THE HISTORY OF BIOLOGICAL THEORIES

BY

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from the German
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TRANSLATOR'S NOTE

My thanks are due to Professor Julian Huxley, who first suggested that Dr. Rádl's work should be made available to English readers, and to Dr. Charles Singer for his expert help and advice in the work of translation.

E. J. H.

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AUTHOR'S PREFACE TO ENGLISH EDITION

IT gives great pleasure to write a book, but the author's greatest joy comes when his labours are ended, and he feels himself free to devote his attention to other things.

When I had completed this book, I found myself in that happy position; and not even the news that the whole edition had been sold provided an impetus great enough to drive me to take up the task again.

For revision became necessary. The book is a history, and history does not stand still. It develops unintermittently, bringing forth new ideas and continually throwing fresh light on the past.

The demand for an English version encouraged me to a renewed effort, and, at the request of the English publishers, I set to work once more, abridging in places, in others making such alterations and additions as seemed absolutely essential to make the present situation clear.

I will not attempt to indicate what I have retained of the 1909 German edition, or what I have omitted. I will rather attempt to summarize, very briefly, the most outstanding changes which have occurred in the position of the sciences since the German edition of the book was published; such changes as are important for a true appreciation of the views here put forward.

That decline of interest in the Darwinian theory which was discussed in the German version, has steadily continued. To the theory that living organisms have developed, the more complex from the more simple, through countless eons of time, and that man has been evolved from an animal ancestor—to this theory of evolution no weighty objection has been raised.

It is true that the theory has not received any clinching scientific proof. But it is, on so many lines of evidence, so

extremely probable, and the objections to it are so slight, that we may, for all practical purposes, safely assume that it is true. But, in the nineteenth century, the enthusiasm for the theory was so great that its upholders expected it to lead to a revolution of our whole civilization; of our social institutions, our politics, and our science; even of our philosophy and our religion.

This revolutionary tendency of the theory has disappeared. Biology itself is no longer as interesting as once it was to the man in the street. It is no longer the leading science in the life of civilized man. Its place is being usurped by theoretical physics, and, at the present moment, by chemistry. Einstein has now placed himself upon the throne formerly occupied by Darwin.

We may indeed question whether Natural Science is the leading discipline in the intellectual life of to-day. It is still the predominating interest of the Anglo-Saxon peoples, though, even with them, the focus of interest tends to be the technical applications of the sciences, rather than the pure sciences themselves.

In Europe, however, and especially in Germany, there is a very general and growing conviction that the nineteenth century over-estimated the importance of Natural Science in the life of the people. The sciences, it is felt, were stressed at the cost of the more purely intellectual subjects. Hence to-day it is the fashion to attach more importance to history, especially philosophical history, to jurisprudence and the more theoretical aspects of sociology.

In view of all these modern movements, should we not ask ourselves whether there is any obvious reason for the condition of stagnation into which some aspects of biological investigation have fallen. Since about 1890 practically no advance has been made in our knowledge of the origin of living organisms. Can this, by any chance, be due to the fact that our methods have been too exclusively the methods of science? It would be quite possible to

treat the past history of the world of living organisms as an historical problem, and to attempt to solve the problem by historical methods. It would then be analogous to the study of the origin of religions or of the various European States. The more I, personally, think on the subject, the more I believe in this method of attack.

We should have to revise our whole methodology and to adapt it to this new conception of the problem. Above all, we should have almost completely to abandon that positivist attitude which characterized the work of the second half of the nineteenth century. This would involve a thorough investigation of Driesch's work on the autonomy of the life processes. Such a study would lead us to realize how analogous are the physical activities of living organisms to mental activities. We should then be prepared to attack the history of the physical as we now study the history of literature, of civilization, or of philosophy.

Let me give a concrete example which will make my meaning clear. We have, so far, always attempted to visualize the physical processes by which man, regarded as a physical structure, was gradually evolved from some lower organism.

The historian might do just this. He might give us the detailed ancestry of an Alexander the Great, a Caesar, a Locke, Dante, or Napoleon, and hold that he had fulfilled his function as an historian by making such an ancestral portrait gallery more complete. But this is not the method of the historian. He describes his heroes as the originators, the protagonists or antagonists of *ideas* which have dominated mankind. He speaks of the development of *the imperial idea*, of *empiricism*, of the *poetry* of Dante.

The world of living organisms seems likewise to be dominated by ideas, and it would surely be worth our while to study these more closely, and, by such a study, to endeavour to throw fresh light on the past. This is, however, merely a suggestion for the future. To-day the biological sciences are facing a time of crisis—a crisis even more acute now than it was twenty years ago, when I first

approached these problems in the German edition of this work.

To conclude. It was a very great age, that second half of the nineteenth century which saw the birth of the evolutionary theory. This book was written to show my readers how tremendously important the conceptions then formulated were. The question of the origin of species had to be raised—it was essential for man's intellectual progress. The Darwinian theory represents a very great step forward—but it was a step forward, not the end of the march. Our goal lies still further ahead, and to march ever onwards should be the task of the generation now living.

E. R.

PRAGUE,
9 January 1930

ERRATA

Page 180, line 6, *for* Fleischman *read* Fleischmann
Page 217, line 23, *for* Ettinghausen *read* Ettingshausen
Page 308, line 5, *for* Leibniz *read* Leibnitz
Page 329, line 26, *for* Mallpas *read* Maupas

CONTENTS

I

THE ADVENT OF DARWINISM

§ 1. *Some Earlier Views Concerning the Origin of Animal Forms.*

IN his *Autobiography*, Charles Darwin writes that his contemporaries attempted to account for the success of his theory by suggesting that men's minds were prepared for it, but, so he tells us, this was not, in fact, the case. He relates that, during the composition of his book, he often discussed the subject of development with other naturalists, but never 'happened to come across a single one who seemed to doubt the permanence of species'. It is easy to believe this, but we may question whether this method of cross-examining friends was very suitable for estimating the contemporary trend of thought. Obviously it could not be exhaustive.

Speculations on the origin of the world are, indeed, as old as man himself. Haeckel rightly claimed Moses as a forerunner of Darwin. The Vedic Poems, which are of immense antiquity, ask 'What was the wood, what the tree from which the framework of Heaven and Earth was formed ? ' The myths of the egg from which the earth arose, of the origin of the Universe from water or from fire, of the creation of the first men, gave early answers to Darwin's question concerning the origin of species.

Studying the first sentences of the Bible, the Christian Fathers propounded many theories as to the commencement of the world. While St. Clement, St. Origen, and St. Athanasius tried to prove that all forms of organisms were produced simultaneously by one creative act, the school of Cappadocia, with St. Basil at its head, taught that God originally created only 'elements', which reached their final purpose by a process of development. St. Gregory of Nyssa and St. Augustine expressed this same idea even more clearly. The very dreams of the early Christians

themselves—their pictures of a lost or of a future Paradise, of the Millenium, of the end of the world—are but expressions of the view that things to-day are not as they once were, nor as they will yet be.

These thoughts, however, expressed a philosophy, a pious belief, a desire born of fear, rather than knowledge based on actual facts. Only in more recent times, and particularly since the eighteenth century, have we come clearly to recognize that Man and Nature have a history. For this view Rousseau prepared the way by his teaching that the natural man is the happy man, and that civilization has a pernicious influence.

In Great Britain the eccentric Scot, James Burnett, Lord Monboddo (1714–99), put forward theories as to the origin of speech, and the development of men from monkeys. Herder was then writing on racial evolution, and seeking to turn history into natural history. Kant, and not long after him, Laplace, formulated the well-known Nebular Hypothesis, suggesting that the Solar System came originally into being according to mechanical laws and as the result of a process of condensation of gases. At the end of the century Cuvier set forth his account of the history of the earth's crust and its living inhabitants.

German natural philosophy was full of similar thoughts. Goethe wrote so much about evolution that Haeckel claims him as a forerunner of Darwin. Although Fichte was much less historically minded, his theory that 'being' is the result of 'doing', that the ego is formed by a world external to it—by the non-ego—constitutes something in the nature of a metaphysical embryology of nature. In Schelling we hear echoes of the old doctrine of the *natura naturans*; we still have, that is, a dynamic view. Evolutionary ideas formed the pivot of Hegel's philosophy. He looked on the world as a manifestation of developing intelligence, beginning with a logical idea and passing through unconscious nature to self-conscious man, and ultimately to social organization, to knowledge, art, and religion.

Hegel's influence upon historic thought in Germany, France, Russia, and elsewhere, is fully recognized.

Nevertheless, these evolutionary views of the earlier nineteenth century differed greatly from the modern ones. Darwin sought to make his presentation historical. It is based on the thought that the history of the world is full of events; that every transformation of one organism into another presents the world with a new fact; and that there have been an infinite number of such facts. Goethe, Fichte, Schelling, Oken, Hegel, Braun, von Baer—all these thinkers paid attention to the events by which evolution proceeds, merely to deduce therefrom a law of development, an idea. A change from the older idealistic to the newer realistic conception presented no great difficulty. This is made very clear by the works of Strauss and Feuerbach, Hegel's pupils, in whose hands the idealistic teaching of their master became pure materialism.

Moreover, evolutionary ideas were not absent from pre-Darwinian technical biology. It is true that the views of Lamarck were not generally accepted, but his writings were read, apparently with ever-increasing interest. The fate of his theory in France is well known. In England Lyell (1830) referred to him in his *Geology*, and doubtless directed the attention of many readers to Lamarckism, for while speaking of the Lamarckian theory as a 'phantastic romance', he admired the assiduity of Lamarck's defence of a forlorn hope. Von Baer says that, in the Germany of his day, almost all the older scientists had read Lamarck's *Philosophie Zoologique*.

The Morphologists were at that time occupied in arranging living organisms in series of ever-increasing complexity. Beginning with the simplest, they passed by gradations to the most highly developed forms. They were steeped in the belief in Nature's creative force, and they spoke of the 'Progress' and the 'Perfecting' of these forms. To most these were but abstract ideas, yet there were some who understood by 'progress' a perfection which required

long periods for its attainment; some even occupied themselves in constructing what were, in effect, genealogical trees of animal descent. A certain Kaup, for example, gave the following stages in development:

Dolphin—Seal—Sloth—Elephant.
Tortoise—Horse—Rhinoceros.
Lizard—Black-cock—Stag.

How vital was the interest in this question can be seen from the fact that the University of Munich, in 1834, offered a prize for a thesis on 'The Causes of the Mutability of Species'.

The decline of formal morphology gave a new impetus to the genetic point of view. Scientists became more and more aware that an organism is by no means a 'torpid crystal', but that, standing in living inter-relationship with its environment, it is ever in a state of change. The interest in morphology was replaced by an interest in embryology, which gave a truer picture of life, in that it endeavoured to portray the origin, development, and death of the individual body. Von Baer the embryologist was then one of the moderns.

We can follow these changes in point of view if we consider the various current ideas as to the vertebral origin of the skull. Goethe (1790) was the first to express the view that it is formed on the same plan as the backbone. In the early nineteenth century this idea was much in favour and was expressed in various ways. Some thought of the skull as a single modified vertebra. Goethe had at first assumed that three, and later that six vertebrae went to its formation. Oken expressed a similar thought in more extreme form, considering 'the whole Man a vertebra'. Geoffroy extended the conception farther, and regarded the insect body likewise as composed of vertebrae, assumed to be external, the organs being internal. Others, for example Carus, professed even more fantastic views. All were variations on the theme that the vertebra is repeated in numerous parts of the body.

In considering these bizarre views of the older morphologists we should remember that they did not visualize a concrete vertebra as repeated in every part, but a generalized recurring vertebral plan. As Goethe expressed it—'Identical parts undergo manifold transformations under the action of a vital force.'

The theory of the vertebral origin of the skull was supported in England by Owen and challenged by T. H. Huxley, one of the younger anatomists full of von Baer's developmental views. Huxley objected to it on embryological grounds. He held that although in the earlier stages of development the skull is segmented, as is also the rudiment of the backbone, yet from these similar beginnings skull and vertebral column develop along wholly different lines.

Yet Huxley's view, opposed as it was to the forms of the theory expressed by Oken, Carus, Owen, and others, was in no sense a contradiction of that of Goethe, but rather a modern version of the same thought. Nevertheless the expression adopted by Huxley shows clearly the change in point of view with the advance of time. Belief in a foreordained plan had been replaced by belief in development. This was, for the moment, only embryonic development. Soon, however, the word took on a wider meaning and came to signify an historical development.

With this renewed interest in embryology, palaeontology, the true science of the history of creation, also increased in prestige. To Cuvier palaeontology was a department of geology. Blainville already placed it near zoology, including living and extinct animals in one series; we probably see here the influence of Lamarck. Palaeontological knowledge quickly increased. About the middle of the century, there began to appear in Germany popular works with such titles as *A History of Creation.* These paved the way for the diffusion of the evolutionary idea. By 1851 palaeontology was so much in the vision of naturalists that Vogt subdivided zoology into (1) palaeontology; (2) morphology of existing animals; (3) embryology.

There were many distinguished biologists who not only came near to the idea of evolution proceeding in time, but who already recognized that the problems of evolution are the most fundamental in biology. Thus in 1833 von Baer the embryologist lectured on the subject of 'Natural Law in Development'.

'The problem of Creation', said the lecturer, 'is the fundamental problem of biology; when that is solved, all others become clear. Observation of living things in our own time shows the individual passing away, but the species surviving as the expression of a definite thought. Yet observation based on wider knowledge, especially on palaeontological grounds, leads to the conviction that even the species is not eternal. It appeared at a particular moment in world history, and later disappears again. We do not know how it first arises. Each species must either have arisen through a special act of Creation, or must have arisen from some pre-existing species. A new creation may have taken place many times. But if the species dies out, what is it that continues? Does not the whole mystery of existence lie hidden in this history of species? And what is its meaning? Since the history of Nature is a history of continual advance from the less to the more perfect form, must we not answer—"the History of Nature is but the history of the increasing victory of the spiritual over the material?"[1] That is the essential idea of Creation.'

This discussion contains the germ of a transcendental evolutionary philosophy, and propounds questions that none can think solved. Many others agreed with von Baer; Bronn the well-known morphologist and palaeontologist, the botanist Braun, the entomologist Burmeister, the French physiologist Milne-Edwards, the German physiologist Johannes Müller, the biologist Treviranus, and many others. These differed indeed in their solution of the problem, but the fact remains that in the second quarter of the nineteenth century most of the great

[1] C. E. v. Baer, 'Das allgemeine Gesetz der Natur in aller Entwicklung', *Reden*, i, p. 72.

biologists were following these evolutionary questions with interest.

Moreover, the problem of the origin of man was being seriously discussed in Germany, in the forties, under Herder's far-reaching influence. Max Müller cites a treatise which, by an act of irony, appeared in 1840 in a theological newspaper! This treatise set out to show that man has developed from the monkey! Later, when Darwinism held the field, naturalists sought for and found his forerunners in numbers. Blinded by the brilliance of the new theory, they looked upon it as an absolute truth—a truth in no way connected with the thought of the time, but the discovery of a genius. The duty of the historical writer was to search history for other geniuses of lesser rank, who had stumbled on this truth that had been completely revealed by Darwin. They did not sufficiently analyse Darwin's fundamental ideas. They gave too much consideration to certain minor points in his theory, and so declared those to be the forerunners of Darwin, whose thought had in fact scarcely approached his. In almost every philosophical writer from Empedocles and Aristotle to Goethe, the inquiring eye of faith of some historian would discover a masked Darwin. And yet the idea that there can be 'something new under the sun' had contended vainly for recognition in the eighteenth century, not to speak of earlier times!

Empedocles is cited as a forerunner of Darwin. He taught that present-day organisms had arisen by the union of parts (heads, hands, feet, and so on), which united quite by chance and in all sorts of combinations. Only after the destruction of various irregular forms did they come together in their present shapes. It is forgotten that Empedocles—a Pythagorean—believed in the eternal changelessness of all creation; it is overlooked that his theory is as little Darwinian as is modern chemical theory, according to which the manifold forms of matter arise by different combinations of the same eternal, indestructible atom. If Empedocles be a Darwinist, so also was the first

unknown Roman who named the leopard *leo-pardus*, the giraffe *camel-leo-pardus*, names which suggest that these animals arose from a cross between lion and panther and between camel and the lion-panther cross. In the Middle Ages there was a persistent belief that a man and an animal could conceive a being half-animal, half-man. This, too, was just as much and just as little a Darwinian conception!

§ 2. *The Influence of Geology.*

In the early nineteenth century geological thought was dominated by Cuvier's assumption that the face of the earth had undergone many changes. He believed that these had been caused by sudden catastrophes or cataclysms. Cuvier sought to harmonize this view with the known facts concerning extinct animals. He suggested that the whole organic world was almost completely destroyed at each upheaval, and that later, new forms appeared in the devastated regions. He made no attempt to explain whence these new forms came. Very different opinions were held about the cause and number of these catastrophes.

In Germany there were two schools of geological thought. The 'Neptunists' asserted that all mountains originated in water; the 'Vulcanists' that they were due to heat and volcanic action. Just as great diversity characterized the theories as to the number of these upheavals. The French geologist Elie de Beaumont (1798–1879) at first thought that there had been seven, then he suggested twelve, fifteen, sixty, even a hundred as the probable number.

Morphologists, at this period, were comparing the living body to a crystal, and seeking for its symmetry. This way of thinking influenced geological speculation. Elie de Beaumont suggested, in his theory of the genesis of mountain chains formed by the cooling and shrinking of the earth's crust, that they lie on the sides of a regular rhombic dodecahedron circumscribed about the earth!

In England, where geology was a study of long standing,

its problems were attacked more practically. Charles Lyell, a lawyer and journalist, published his great *Principles of Geology* in 1830–2. He rejected the catastrophic theory, and explained most geological phenomena as the result of slight and slow changes similar to those still taking place. The forces at work are such as the attrition by rain, or the action of subterranean streams and lakes which undermine the solid crust, or volcanic action, which causes a rising or sinking of the surface of the earth.

The influence of Lyell's theories was immense, and even to-day their essentials are accepted by geologists. It is true that in practice we distinguish between epochs—we speak of primitive rocks, of palaeozoic, mesozoic, tertiary, quaternary epochs, and the like,—and that we further subdivide each of these. We know in practice that the different formations of different periods have definite distinguishing characters. We speak of causes, of which, it is true, we know little, bringing about the transition from one period to another, nor do we reject the possibility of non-terrestrial forces having contributed to these changes. In our theoretical considerations, however, both the earth and the human race are always thought of as possessing a continuous and unbroken history, and this attitude we owe largely to Lyell.

Lyell's work had a lasting effect upon Darwin. Throughout his voyage round the world Darwin had Lyell's geological views in mind, and after his return to England he published a series of observations which seemed to him to support them. Later, when inquiring into the origin of species, it was therefore natural for him to attach great importance to the slight changes continually in progress around us. He kept in mind Lyell's view of the great antiquity of our earth, and the possibility of great alterations being the result of the summation of gradual action over a vast period of time.

The views of Lyell on the origin of life resembled those of Cuvier. He thought that climatic changes had forced animals and plants to migrate, and that the presence of

varying forms of life in successive layers of the earth's crust was explicable on the basis of these migrations. In the very first of the numerous editions of his *Geology*, however, Lyell had drawn his readers' attention to Lamarck's theory, and his letters show us that, from the year 1827 onwards, he was fully alive to this idea of change in living forms, and was inclined to accept the new hypothesis.

§ 3. *Vestiges of the Natural History of Creation.*

In 1844 the attention of literary England was directed to the anonymously published *Vestiges of the Natural History of Creation*. The book was generally attributed to Robert Chambers (1802–71), a journalist, traveller, and historical writer with some knowledge of geology. It was widely read both in English and in translations. In 1884 the twelfth edition appeared under Chambers' own name. It dealt with the origin of the world and of its animal inhabitants. It assumed that the living world was started on its path by Divine Providence and that life owed its origin to a chemico-electric process. By this process germ cells were created, and from these new and ever-changing forms were produced by discontinuous gradations, which gradually advanced towards ever greater perfection. These progressive grades were held to be analogous to the changes seen in the metamorphosis of jelly-fish, tape-worms, or insects. That species can undergo modification was illustrated by appeal to the supposed change of fungi into algae, and of wheat and oats into rye. A raven had once been seen with a beak like that of the sheldrake; and the domestic pig can revert to its wild form. Living and extinct transitional forms were cited, as, for example, certain reptiles, which were thought to link fishes and snakes with crocodiles. The river lamprey (*Petromyzon fluviatilis*) was thought to be transitional between the worm, echinoderm or cephalopod, on the one hand, and the fish on the other. So too the frog, dolphin, sloth, bat, point the way towards man, who probably arose from a large frog which ultimately became extinct. The author drew a

parallel between the animal series and embryonic and palaeontological development, and pointed to the significance of vestigal organs, and of the anatomical similarity between different animals.

The *naïveté* of the outlook of the *Vestiges* roused the antagonism of men of science, who nevertheless read it eagerly. Wallace and Bates were stimulated by it to consider the origin of species (1848). It even influenced Darwin, who committed his views to paper for the first time and communicated them to his friends in the year of publication of the *Vestiges*.

II

CHARLES DARWIN

§ 1. *Charles and Erasmus Darwin.*

CHARLES ROBERT DARWIN was born in Shrewsbury in 1809. As a boy he was a great collector of natural history specimens. The ordinary school work, however, did not attract him, neither, as he grew older, did medicine nor the suggestion that he should train for the Church. Following his natural bent he early devoted himself to biological studies.

He came of a well-to-do family in which an interest in natural science can be traced back throughout the eighteenth century. His grandfather, Erasmus Darwin (1731–1802), excelled not only as a physician, but as a poet, man of science, and philosopher. Erasmus was much influenced by Rousseau, whom he knew personally. He adopted methods of 'natural healing' and endeavoured to hasten the patient's recovery by influencing his mind. He also turned his attention to the cure of inebriety, with, it is said, great practical results. As a poet he sought to discuss botanical problems in verse, and founded in England a peculiar school of descriptive scientific poetry. As a man of science he made many new observations on subjective vision and on vertigo. In this original work he was a forerunner of Purkinje. He published two extensive scientific works, *Zoonomia or the Laws of Organic Life* (1794–6) and *Phytologia or the Philosophy of Agriculture and Gardening* (1799). These are based on the realistic philosophy of Locke and Hume in an original, and sometimes in a laughable manner. The main object of these works is to explain the nature and origin of life.

It was the view of Erasmus Darwin that God had originally created one living substance from which some very simple form of organic life developed. Gradually, from this, all animals and plants arose. He suggested the

ideas of mimicry, and of sexual selection, and sought to explain conditions prevailing in the world by an appeal to our every-day experience.

Charles Darwin made very little effort to relate his theory to that of his grandfather. His great dislike of abstract philosophy made him undervalue his grandfather's work, as he undervalued that of Lamarck. He failed to realize that scientific thought and scientific theories are of slow development—that these, too, have a history. He looked upon the theories of both men as very fantastic.

The work of Erasmus Darwin was quite overshadowed by the great success of that of his grandson, and he was regarded as little more than an unimportant forerunner of the great Charles. Nevertheless, Erasmus was richer in original ideas and had a much greater literary insight than his grandson. The grandson was the superior in thoroughness and perseverance.

Charles Darwin, after his return from his voyage round the world, mingled in London with the most cultured Englishmen of his day. Among his friends were Lyell the geologist, Whewell the philosopher and author of the *History of the Inductive Sciences*, Robert Brown the botanist, Buckle, author of the *History of Civilization in England*, Macaulay and Carlyle. He constantly discussed their views with them. In his *Autobiography* he criticizes them in a manner that reveals him as the typical cultured Englishman of his day; while able to say something polite about each of them, he exhibits little real insight into their characters and less understanding of their fundamental ideas.

Darwin was greatly impressed by Buckle's work—by the tremendous knowledge it displayed, and the methodical way in which facts were gathered from the most diverse sources for use in support of his theories. For Carlyle, on the other hand, not only had he no sympathy but he regarded him with ill-concealed derision. If it be true that a man's estimate of another be the best clue to his

own character, we may look on these facts as significant. The remark of Darwin concerning Carlyle, who was dowered with a rich fancy, is eloquent enough. 'As far as I could judge,' says Darwin, 'I never met a man with a mind so ill adapted for scientific research.'

Darwin has told us that the two men whose work greatly influenced him during his student days were Herschel and Humboldt. He made a collection of abstracts from Humboldt's writings, and was glad that he was about to travel 'as Humboldt had done'. He began this journey in 1831 in the *Beagle*, a ship fitted out by the English Government to explore the coast of South America. During the voyage he was chiefly interested in geology. Lyell's book had recently appeared, and in South America Darwin sought evidence in support of Lyell's theory of gradual changes in the earth's crust. He also followed on Humboldt's line of work, being much interested in the geographical distribution of plants and animals. After his return from the voyage in the *Beagle* he took no post, but gave his whole time to his scientific work. Much of his life was passed in the seclusion of a country residence. He died in 1882.

Members of the Paris Academy accused Darwin of dilettantism. He belonged to no school, was neither botanist nor zoologist, geologist nor physiologist; he followed none of the prevailing lines of thought; he was neither morphologist nor embryologist. He gave his attention to one question after another, passing from an explanation of the origin of coral reefs to the question of the origin of species, from the study of the movements of plants to that of mimicry and to the development of the human face. The theories which he originated are extremely English in form. They are founded on experience rather than on reason, and are original but not profound. The arguments are monotonous and embody little searching of the mind. The greatness of the work lies rather in its system and in the multiplicity of the phenomena cited in support of its theories.

§ 2. *The Starting-point of the Darwinian Theory.*

At the end of the eighteenth and beginning of the nineteenth centuries the teaching of the utilitarian philosopher Jeremy Bentham was spreading in England. Bentham taught that morality is based on man's likes and dislikes, that the moral is merely the useful, that man only avoids sin because he fears discovery and its consequences. The individual, it is true, cannot give free rein to all his desires, but he need only control them when they conflict with the interests of society.

'The greatest happiness of the greatest number' is the keynote to this egoistic morality. It sought the origin of the moral sense in man's social life, with its inevitable conflicts between individual interests, rather than in some inborn quality of the human soul. Bentham's work, in which these ideas were developed, appeared in 1789. In 1778 Adam Smith had published his *Wealth of Nations*, a treatise dealing with the laws of political economy. According to Smith, man is an egoist relentlessly pursuing his individual aims. That society will become the most wealthy which does least to restrain the individual in the economic struggle, which leaves him free to buy in the cheapest and sell in the dearest market.

These moral and political ideas—for the analogy between the two is obvious—fell in England upon fertile ground, and became the foundation of the so-called *laissez-faire* school of political economy. The country was in process of transformation from an agricultural to an industrial state, and the big industrialists found in Adam Smith's teaching good arguments against various protective laws, privileges and taxes which they disliked. More and more the ideal state was assumed to be one that merely protected the freedom and property of the citizen, without hampering his individual liberty, and laws and regulations which did not fit this view were gradually repealed.

The work of the philosophers of the period was a strange medley of logic and psychology. Writers would begin

their observations with some psychological analysis. They would take one phenomenon, selling, for example. They would examine the psychological processes connected with it and deduce one or two fundamental catch-phrases, as for example, 'supply and demand'. They then discussed these as the driving principles in the 'selling process'. They would endeavour to deduce the result if a community should obey the one law 'buy cheap and sell dear'. Thus they reached conclusions which they believed to be as important as facts elicited by observation and dependent upon natural laws.

Thomas Robert Malthus (1766–1834) in his *Essay on Population*, first published in 1798 and often reprinted, followed the same type of reasoning. His axioms are well known. That mankind is always striving for happiness served as his starting-point. Then followed the question —Why has man's longing for progress so little result? If we look at the life of the community more closely, said Malthus, we see that man has an inborn desire to reproduce his kind. Food too is needed that he may live. These, the desire for food and the desire to multiply, are the driving forces behind all human progress.

How, by considering the antagonism between these two factors, Malthus continued, can we arrive at present conditions? Man increases rapidly, in geometric progression, but his available food only in arithmetic progression. Hence must arise shortage of food, hence hunger, disease, overwork, under-feeding of children, overcrowding, war, and all manner of disaster. From this he inferred that man, to be happy, must restrict his desire to reproduce. The happiness of mankind becomes the controller of each individual's tendency to over-multiply.

These views of Malthus aroused considerable discussion, and in 1834 we trace their influence in the changes in the English poor law. The liberal movement reached its height in the thirties, after the July revolution in France. The same line of thought was followed still further. It was continued and further worked out in Buckle's *History*

of Civilization in England (1857–61). Buckle strove to convince his readers that history should become a science. The subject-matter of this science was to be the laws of the human spirit and the influence of such factors as climate, soil, food, &c., upon mankind.

Such were the thoughts which dominated England when Darwin appeared. He was, it is true, neither a professional politician nor a political economist. It is possible that he had never read Bentham or Smith; he says nothing of the influence of Mill on his views. But he had read Malthus, he tells us, in 1838, when he had been considering the origin of species for over a year. The influence that the ideas of Malthus exerted on him is seen in the second edition of his *Journal*. It is well known that he accepted the Malthusian view of over-population and deduced from it the struggle for existence. What is not so fully recognized is that the influence on him of these theorists in political economy was very great—that his whole conception of nature, his whole scientific outlook, was dominated by them.[1]

All pre-Darwinian writers, not excepting Lamarck, saw in Nature individual animals and individual plants, whose bodies and bodily functions were similar and subject to similar laws, thus testifying to an underlying unity. They often spoke of 'Nature', but for them this word meant a spiritual or even a mechanical principle which, working according to definite law, gave rise to the phenomena of the physical world. The individual, whether plant, animal,

[1] The *Origin of Species* was a very large book, and its subject-matter was very new. These two characteristics probably account for the fact that the close resemblance between Darwin's reasoning and the logic of the *laissez-faire* economists passed unnoticed.

The reader should examine Darwin's paper, 'Extracts from an as yet unpublished work on the idea of Species' (which was read before the Linnean Society in 1858, simultaneously with Wallace's paper), if he wishes to see how similar the two really were.

Darwin's paper is quite unmistakably written on the pattern of the *laissez-faire* economists. It is hardly more than an application of their reasoning to the facts of nature, and in this paper he refers to Malthus' theory more than he does in his later work.

or man, was but the expression of an eternal law. The destruction of the one, of the many, of the whole world, meant nothing more than the disappearance of the visible manifestations of eternal laws—laws quite independent of life and death.

For Darwin, however, true son of practical England, Nature consisted of separate parts. The death of an individual meant for him a change in Nature, the death of a hundred such, a hundredfold greater change. He looked at the whole living world from the point of view of the political economists. It consisted of a society, a state, of separate plants and animals, each following its own individual impulse. The economists pictured the state as a unit consisting of individuals whose egotism was only held in check by the egotism of others. So Darwin thought of Nature as made up of individuals, each following his own interests and living his own life. Thus he arrived at a new and wonderful conception, the view of plants and animals as members of a community—the community of Nature. The Liberalism of the day denied to the state the right to limit individual freedom; Darwin combated the belief in any higher law which controls Nature and regulates the relations of animals to each other. Laws only arise from the combined individualistic tendencics of the plants and animals themselves.

It is impossible to understand why Darwin influenced the sociological theorists so profoundly, unless we realize that his whole teaching really constitutes a sociology of Nature, and that Darwin merely transferred the prevailing English political ideas and applied them to Nature.

He took his logical method from Malthus. He began from a single definite fact, based on observation, namely, that the number of individuals increases at a rapid rate. He considered what would be the result of this tendency should it act unchecked; he concluded that it would lead to a struggle for existence, and he called the deduction thus arrived at a 'natural law'. *Laissez faire, laissez passer; la nature va d'elle même* was the famous watchword

of those times. The politicians emphasized this doctrine on the practical side to prevent the state from any active interference in the rights of its citizens. *Laissez faire, laissez passer* was the negation of the old law of the divine right of kings. Darwin, in his theory, accepted the second half of this sentence and wrote his book on the theme *La nature va d'elle même*. There is no God-given law in Nature.

§ 3. *Darwin's Theory.*

Darwin began with two assumptions; firstly, that the species is an artificially determined group of existents, and, secondly, that present-day forms are the results of selection.

1. When Darwin commenced to study the question of species many views on the subject were in existence—those, for example, of Buffon and Linnaeus, the definitions of Cuvier, the ideas of Lamarck and of such morphologists as the De Candolles. But Darwin ignored such 'philosophic' discussions. His method was to collect, from works on floriculture, entomology, gardening, and animal-breeding, cases in which the author could not say whether a certain plant or animal constituted a variety or a species. He showed that there was no general agreement on the subject, and drew attention to the way in which new species are created by the specialists.

'Practically, when a naturalist can unite by means of connecting links any two forms, he treats the one as a variety of the other; ranking the most common, but sometimes the one first described, as the species, and the other as the variety' (*Origin of Species*, 1895, p. 34).

Since the practical man often finds it difficult to distinguish between a species and a variety, the two cannot be fundamentally different. A variety is a minor species. There are many different categories classed as varieties; some are quite definite, others distinguished only by almost invisible differences. As we can point to no constant standard of difference, there can be no definite boundary between those characters that constitute a

variety and those which merely represent individual variations.

'From these remarks it will be seen that I look at the term species as one arbitrarily given, for the sake of convenience, to a set of individuals closely resembling each other, and that it does not essentially differ from the term variety which is given to less distinct and more fluctuating forms. The term variety, again, in comparison with mere individual differences, is also applied arbitrarily, for convenience sake' (*Origin of Species*, 1895 edition, p. 39).

Darwin thus revived Leibnitz's formula *Natura non facit saltus*. This famous axiom was given currency by Linnaeus. It was common to all biological theories of the eighteenth and early nineteenth centuries, and it was given many different interpretations. Once more, Darwin made no attempt to discuss these earlier views, no effort to show how much of them would be superseded if his own theory of transitions were accepted. He rather treated them as mere anticipations of his own correct doctrine.

Neither Darwin nor his followers observed that the phrase *Natura non facit saltus* was used by him and by Leibnitz to express widely different views. To Leibnitz, as to all eighteenth century thinkers, the phrase expressed the belief that the entire range of living organisms was an embodiment of the series of very fine shades of difference, in the Original Thought of which they are the varied manifestations, that is, they differ in essence. It was just this idea that Darwin and his followers combated in using the same words. They asserted that between isolated phenomena there are only unessential differences; in Nature things merge by insensible gradations one into the other, just as, for instance, the hamlet becomes the village, the village the little town, the large town, the city. The distinction between these terms is merely a matter of arithmetic, or of an arbitrary scale in the minds of those who use them.

We must particularly emphasize that to Darwin such quantitative differences were the *only* differences that

existed; not only between species and varieties and individuals, but between all things whatsoever—between men and monkeys, between morality and immorality, between the tertiary formations and the diluvial strata and so universally.

Darwin welcomed every new case which could be regarded as an illustration of this teaching. He was content merely to prove that there are such transitions. He knew that Linnaeus believed in the constancy of transitional forms, and had come to the conclusion that species are immutable, but he does not seem to have considered it necessary to inquire how he came to hold so very different a view.

2. Darwin went on to explain how links between species may arise. He shows, referring to many examples, that descendants of the same parents differ greatly from each other, as well as from their parents. Once more, he stresses the number of his examples without making any sustained endeavour to analyse them. Nevertheless, he gives the following causes which will tend to make individuals of the same species differ from one another.

(*a*) The direct influence of the environment, for example, more ample nourishment causing stronger growth.

(*b*) The indirect influence of the reproductive organs, which he assumes to be very sensitive to every kind of impression.

(*c*) A change of habit. The domestic duck is forgetting how to fly, the ears of dogs hang as the result of disuse. In some cases a change in one quality will induce a change in another—long-legged animals, for example, tend to have long heads; organs of which the animal possesses more than one, rudimentary organs, and those of simple structure, show most variation.

The features distinguishing individuals show the greatest tendency to variation; those marking varieties are more constant, those characterizing orders show least variation.

In another place the rule is formulated that the commonest and most widely spread species are the most

variable, and so are the species belonging to the large genera (i.e. in those orders which contain many genera, these genera have many species).

Darwin calls these suggestions variously 'hypotheses', 'causes', 'rules', or sometimes 'laws'!

3. He terms the fact that offspring resemble their parents, *heredity*; he shows that children inherit from their parents not only their common human characteristics, but their individual ones.

> Perhaps the correct way of viewing the whole subject would be to look at the inheritance of every character whatever as the rule, and non-inheritance as the anomaly' (*Origin of Species*, p. 10).

Thus he believed that the children of English workmen inherit large hands, that chewing coarse food has strengthened the facial muscles among primitive peoples, that the hard skin on the soles of the feet has been developed by walking.

When he had collected his material concerning inherited characters, he arranged it so that it illustrated the following 'laws':

(*a*) If the parents acquire a character at a certain age, it will show itself in their offspring at about the same age. The chickens of various breeds of domestic fowl are closely similar but differentiate as they mature.

(*b*) Periodicity is an inherited factor, e.g. the periodicity of the colour change in those animals which have a winter and a summer colour.

(*c*) The characters of the father are often inherited by his sons, those of the mother by her daughters, e.g. the horns of deer are only inherited by the males. Some characters, however, can be passed on to both sexes, hence the male has a trace of mammary glands, organs which functionally are purely feminine.

(*d*) Man artificially produces new varieties in the following way:

When a deviation from the type occurs (as, for example, a large crop in a pigeon) the animal is used for breeding

purposes. The offspring inherit the deviation, some in greater degree than others. Those in whom it is most strongly marked are again used for breeding, and so, by artificial selection, a new variety of pigeon is produced—the pouter pigeon. Taste and requirements determine the variety produced. The individual variations are the passive material which nature provides by 'chance', and from these man selects. The nature of the different types of dog, pigeon, rose, carnation, and all the other artificial varieties by which modern man has surrounded himself, cannot be understood merely by a comparative study of existing forms. The taste of the hunter, of the pigeon-fancier, of the gardener, &c. must be considered.

(*e*) The Struggle for Existence. A bitch generally bears more puppies in a litter than she can adequately nourish. So her owner drowns some of them, and by the death of their brothers, the survivors flourish. Similar processes, Darwin said, are at work in Nature. Plant and animal life is such that not all the offspring produced can survive. The increase is too rapid. A plant which produces two seeds annually would be represented by a million descendants at the end of twenty years, if all the seeds met with favourable conditions and survived. The elephant increases more slowly than any other animal, nevertheless if we started with one pair of elephants, we should, seven hundred and fifty years later, have nineteen million individuals if all lived to old age and bore offspring at the normal rate.

Experience teaches us, Darwin continues, how field-mice, caterpillars, &c. increase when two favourable seasons follow one another. Nevertheless, the number of individuals in each species tends to remain constant, as large numbers of them disappear before maturity. Eggs and seeds are destroyed, the organisms die young or come to an untimely end, sometimes killed by unfavourable weather, sometimes by hunger, by predatory animals, by parasites and epidemics. This is what Darwin called the 'Struggle for Existence'. We need not assume that the fundamental characteristic of life is a striving, an inner

urge, or that the animals actually fight for life. It is circumstances that so order it that while some die early, others survive. And it is these natural external circumstances which constitute the struggle for existence.

(*f*) The result of this struggle is Natural Selection. Let us assume, says Darwin, that there is a fleet-footed animal inhabiting a district where wolves capture their prey by strength, agility, and swiftness. Wolves differ in individual qualities. The swifter will get food more easily than the less swift and so will increase the more rapidly. Hence the fleet of foot in each generation will survive, and a race of swifter wolves will replace their slower ancestors.

It is difficult to give any general rules for the way in which Natural Selection will act. Individual variations do not seem to follow any law. Many and various are the conditions which cause the destruction of one deviation, the maintenance of another.

In general we can say that it is in the common species, containing many individuals and showing a great tendency to variation, that departures from the mean appear most readily, and such departures often survive. Further, the more ancient the species, the more varied become the districts it inhabits. Individual variations are the starting-point for new varieties—new varieties lead on to new species, and so on. If natural selection continues to act for a long time, changing conditions will give rise to new varieties and after still greater periods to new species, genera, &c. Thus, after millions of years, from one, or, at most, a few original forms, the whole catena of life has been evolved.

'Thus, from the war of nature, from famine and death, the most exalted objects which we are capable of conceiving, namely, the production of the higher animals, directly follows. There is a grandeur in this view of life, with its several powers, having been originally breathed by the Creator into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being evolved' (*Origin of Species*, p. 403).

Darwin suggests here, as in other places, that his idea is comparable with Newton's discovery of gravitation. As Newton discovered one law which all heavenly bodies obey, so Darwin discovered one law for all living things. Darwin indeed went further than Newton. The latter revealed *one* property common to the sun, the planets and all earthly bodies. The former explains, through the struggle for existence, not one but almost all the attributes which differentiate living organisms from one another. This great difference has been the cause of considerable confusion among Darwin's more ardent followers.

We have given the chief features of Darwin's theory, leaving out minor points which will be dealt with later. We may, however, mention a few of the deductions which he thought might be made from his theory.

With the exception of a few general characteristics of living substance, which he did not define more closely, Darwin thought that every feature of the organism had developed by chance. Nothing had meaning in itself, nor would it have developed had not those special circumstances which produced it existed. It is true that animals show a unity of plan. This uniformity, we now see, expresses their common origin. Homologous structures are inherited from a common ancestor. Analogous structures are adaptations to similar needs. The whole system of organic beings is merely a genealogical table, with the simplest organisms at its beginning, the most highly organized (which are to be regarded as the descendants of the simple forms) at its end.

§ 4. *Some Peculiarities of Darwin's Theory.*

The object of the new theory was to describe the events in Nature which give rise to new species, and so to understand the processes of Nature that we can relate the story of past ages. Darwin's aims were diametrically opposed to those of most of his predecessors. They endeavoured to find universal concepts which would include the multifarious activities of Nature; he sought to obtain a clear idea of her

separate phenomena. Formerly reason was considered the only eternal reality—appearances (phenomena) were but fleeting images of that reality. To Darwin, 'the way things happen'—external events—are everything; reason and general ideas he absolutely neglects. He ignores everything that seems to deal with abstract ideas, with logic. He has no interest in the theories of his predecessors. He makes no attempt to analyse the teaching of Lamarck, of Erasmus Darwin, of Agassiz, of Kölliker, &c.—it does not seem to have occurred to him that he should endeavour to understand them. He calmly writes that he does not understand the views of Cope (who was a disciple of Lamarck). In his works is hardly any discussion of the theories of others.

Darwin attacks the view of a species which was current in his day, since he believes it to be false; but he never attempts any critical analysis of this erroneous idea. He does not even define his own concept, and it is characteristic of his whole attitude that the concept is not capable of definition.

For it was just that fact which constituted his proof that there are no definite ideas, no fixed rules, in Nature.

Try to discover Darwin's view on any general question! Each body possesses certain capacities; can these capacities (the functions) affect the body (change it, for example), or are they merely a consequence of the bodily structure? The two views had long been in dispute. What side does Darwin take in the controversy? Which does he consider to be the cause and which the effect?

> 'It is, however, difficult to decide, and immaterial for us, whether habits generally change first, and structure afterwards; or whether slight modifications of structure lead to changed habits; both probably often occurring almost simultaneously' (*Origin of Species*, p. 131).

Has not this answer all the characteristics which made those of the Delphic Oracle famous?

The genealogical tree gives the first clue to the true

relationships of animals, says Darwin; only through it does a 'natural series' acquire any meaning. He conscientiously adds that minerals can also be arranged in a natural series; but at that point he breaks off!

One asks why, if a genealogical tree is necessary to explain the series of living forms, is it not necessary to explain the mineral series.

'We know, for instance, that minerals and the elemental substances can be thus arranged. In this case, there is, of course, no relation to genealogical succession, and no cause can at present be assigned for their falling into groups' (*Origin of Species*, p. 342).

By this method Darwin makes any criticism of his teaching difficult. He explains the origin of species by natural selection, by artificial selection, by sudden changes, by correlated modifications, but he does not indicate the limits of any one of these explanations.

When Nägeli pointed out to him that there are many forms of life which cannot be explained by natural selection, Darwin modestly admitted that the principle could not have so universal an application as he had supposed. He never committed himself, never said how widely the idea could be applied, nor did he even state precisely in what cases it failed, so that this admission was only of academic value and did not influence the further development of his theory. (*The Descent of Man*, 1871, i, p. 152.)

Darwin objected to definitions because his whole thoughts were centered on the variety of Nature. When he should give a definition he overwhelms his readers with examples of that richness of Nature which seems to mock every definition. A species cannot be defined since so many transitional and irregular forms exist. We cannot define the 'struggle for existence', since so many different phenomena are included under this heading. The fight of a bird of prey with its victim, the mere maintenance of existence by a plant on the desert's edge, the too numerous seeds in some plants' fruits, the parasitism of the mistletoe

on the tree—'in these several senses, which pass into each other, I use for convenience sake the general term of Struggle for Existence' (*Origin of Species*, p. 46).

We must not forget that the word 'species' is also used by him only for convenience.

Try to learn something more definite from Darwin about natural selection. He will tell you that the interrelationship between living organisms is so complicated that we cannot ever foresee how we may help the individual in its life-struggle.

> 'Throw up a handful of feathers, and all fall to the ground according to definite laws; but how simple is the problem where each shall fall, compared to the action and reaction of the innumerable plants and animals . . .' (*Origin of Species*, p. 54).

He enjoys pointing out the tremendous interdependence of living organisms. His whole theory rests on the diversity of cause and effect. The partridge is grey because the hawk has good eyes. The rose smells sweet because the bee likes sweet scents. The amount of clover seed formed depends on the number of cats in the district, for cats hunt field-mice which destroy the nests of humble-bees. Humble-bees are necessary for the pollination of the clover, and so on. Since the interaction of events is so extremely complicated, Darwin can do no more than accumulate observations; his works are full of quotations. He himself helped to make the inquiry into Nature's manifold mysteries exhaustive, for all through his life he was a great observer of natural phenomena.

Darwin gave an excessive time to collecting suitable illustrations of his theory. He wanted to call his work on the *Origin of Species* 'Extracts from a Dissertation on the Origin of Species and Varieties by Natural Selection', and he only left out the word 'extracts' on the advice of his publisher; as if a 400 page book was not enough to lay the foundation of his theory! His friends evidently did not think it enough, and we can constantly read that the book is only to be regarded as a 'first communication', and

that the actual demonstration of his theory is to be looked for in *The Variation of Plants and Animals under Domestication*, which contains the whole of his material. The second part of his book on the 'Origin of Man' is almost unreadable because of the mass of quotations which it contains.

Thus Darwin brought to its culmination that empirical point of view which had characterized English thought from the times of Bacon, Locke, and Hume, to that of Mill and Spencer. He and Mill agreed in another extremely English idea. Mill was the mouthpiece of the teaching of his time, that morality has its foundations in utility; moral behaviour is nothing more than behaviour useful to mankind; to die for your country is moral because it is useful to society, to the country.

Darwin explained the origin of species by the same principle of usefulness. Everything that we know of an organism is or has been useful to it, and this usefulness is the cause of all the phenomena of life. There are just a few attributes which are not obviously useful to the organism, as, when a mechanic makes a machine out of iron, the machine will be black because the iron is black. But

'With these important exceptions, we may conclude that the structure of every living creature either now is, or was formerly, of some direct or indirect use to its possessor' (*Origin of Species*, p. 150).

Darwin made ceaseless efforts to demonstrate the usefulness of the most diverse structures. The whole question of the relation of organism to environment is very complicated. We have already seen that there is scarcely one instance where it is possible to foretell what attribute will favour an animal in the struggle for existence; nevertheless Darwin attacked the problem boldly. He tried to show how the giraffe throve as its neck lengthened, how the whale profited when it developed the first trace of whale-bone or baleen, the flat-fish when it learned to swim on its side. Utilitarianism is the leading thought in the teaching of

both Darwin and Mill. Those features which are useful to the organism will be retained—the harmful ones will disappear; those neither useful nor harmful may persist or may vanish. The earlier philosophers stood awe-inspired before their ideas of Life, of Purpose, of Unity of Plan, of the Soul, of Beauty, of Endeavour. Darwin replaced all this by his idea of Natural Selection.

In other sciences we see the same tendency to simplification. A variety of phenomena are replaced by one universal principle. Light, heat, electricity, are wave-motions—the properties of matter depend on the nature of elements and molecules, the movement of the planets depends on gravity. But in these cases the principles express the actual nature of the phenomena themselves. We cannot say that there was first a wave-motion, and then light; or first gravitation, and then planetary motion; or that there was once salt which was not produced by the combination of sodium and chlorine. But that is how relationships are formulated in the Darwinian biology.

We cannot assert that 'Natural Selection' or 'Usefulness' *explains* the intrinsic nature of the eye—it is rather the historical cause of its development. The eye was not always as it is to-day—a better one appeared one day 'by chance'; this proved more useful, and so was retained. The Darwinists treated every problem in the same manner. To the questions—Why is the kangaroo found in Australia and not in Europe? Why has man two eyes and not three? Why does the lark sing? Why is the sky blue? Why does a dog wag his tail? we get the stereotyped answer: Things were not always thus: but there came a day when the lark began to sing; some hen-bird liked the song and became his mate; she bore him children who could sing too—and so on.

Once upon a time the dog could not wag his tail; one day a crafty animal noticed that if he wagged it, he could empty his rectum more easily; thus tail-wagging became connected with a feeling of pleasure; the discovery be-

came a habit; it was inherited by his descendants. Now, you see why the dog wags his tail when he is pleased! [1]

You ask—Why is the sky blue? Once, it looked by no means blue, but a steely grey. Man's eye learned to distinguish a blue colour—inheritance—and so on!

There is the essence of Darwin's teaching!

[1] This hypothesis was suggested by Erasmus Darwin.

III

ALFRED RUSSELL WALLACE

THOSE who hold that new ideas originate in the thought currents of an epoch, will find confirmation of this in the fact that Darwin and Wallace lit upon the same theory. Although in upbringing and intellectual disposition the two men were very different, they both came to believe in the transformation of species, they discovered the doctrine of Natural Selection simultaneously, and formulated it under the influence of Malthus.

Alfred Russell Wallace (1823) was for a time a teacher, then a railway engineer, finally a naturalist and traveller. His mentality was distinctly peculiar. He believed in phrenology, his interest in it being a lasting one. In his youth he was an ardent spiritualist. He accepted the miracles of Lourdes. He was strongly influenced by socialist theories. He maintained that the State should not support scientific research, just as it should not support factories for the production of carpet patterns; both only served private ends, and could be safely left to the care of those interested in them. It should, however, encourage the popularization of science.

The reading of the *Vestiges* turned Wallace's attention to the study of the origin of species. Shortly after the appearance of this book in 1847, he and his friend Bates went to the region of the Amazon, to collect 'facts for the solution of the question of the origin of species'.

Bates remained in America, and later came to the support of Darwin with his theory of Mimicry. Wallace, however, returned to England, bringing with him his collection of specimens, but the ship in which he was returning was burnt at sea, and all his belongings were destroyed. He remained in England for two years, then set off once more—this time to the Malay Archipelago—and in 1855 he sent home from Borneo his first communication on the origin of species. Stimulated by reading the

work of Malthus, he sent a second communication in 1858, in which he gave, as did Darwin, 'Natural Selection' (although he did not actually use this term) as the explanation of the origin of species.

Much has been made of this very striking coincidence, but there is little really extraordinary about it. Wallace had for long been studying the origin of existing animals. In a work he published in 1855 he suggested, for the first time, reasons why the animals of consecutive geological periods are nearly related. He had then no idea of causes underlying the transformation of species, nor does he seem even to have considered that such causes may exist. The one fact which he sought to prove was that each species when it arises is 'coincident', both in time and place, with a nearly related pre-existing one. He gives reasons in support of this assertion founded on the facts of geographical distribution, of geological sequence, and on the existence of a natural system.

On becoming aware that there may have been a transformation of species, Wallace began to seek its cause. He read the work of Malthus, and it was an obvious step to apply his theory relating to human progress to progress in Nature. Having adopted the method of Malthus, Wallace could not avoid reaching the ideas of a struggle for existence and of a natural selection, as these are merely the logical consequences of the premises.

In its concrete development, Wallace's theory differs from Darwin's in certain important respects. Darwin was a more abstract thinker than Wallace. He emphasized the struggle for existence, variation, heredity, natural selection —in short, the theoretical side of his teaching. Wallace, on the other hand, attached importance to his examination of the facts of geographical and geological distribution; he compared the faunas of different districts, and endeavoured to show how the animal types occurring in consecutive periods of the world's history were interrelated. He studied the colours and habits of animals more for their own sake than to prove the theory of evolution.

He disagreed with Darwin in several minor points; he thought that one factor—Natural Selection—was sufficient to account for evolution; he refused to accept the doctrine of the inheritance of acquired characters; he also considered that the various races of domestic animals must be looked upon as monstrosities and not analogous to wild races.

Wallace sent his paper on the origin of species to Darwin, asking him to arrange for its publication. It reached Darwin just as he was preparing his own work and caused him considerable embarrassment, for he saw himself robbed of the fruits of his own labour. Finally Wallace's manuscript and certain old letters and manuscripts of Darwin's which treated of the origin of species were published simultaneously.

Later, Wallace criticized Darwin's idea of sexual selection. He thought that the struggle for existence was enough to explain the beauty of animal form and colour. (T. Wallace: *Tropical Nature and other Essays*, London, 1878.) He also threw doubt on those theories that sought to explain the origin of man, pointing out the paucity of our knowledge of prehistoric man. He emphasized the fact that the existence of tertiary man is assumed, but nothing known about him. He combated the assumption that the ancestors of modern man were always less highly developed than he, and pointed out that the inhabitants of many islands, as well as the natives of Central America and the Egyptians, were more highly civilized in prehistoric times than to-day.

Wallace favoured the belief that man is not related to the animal on his spiritual side, but that his soul was breathed into him from a supernatural world. Only thus could he account for mathematical talent, for musical genius, the capacity for martyrdom, true friendship—for, in short, all the highest human qualities and capacities. Many bodily structures, such as the form of the foot, the hand, the upright walk, the naked skin, cannot be explained by any theory of natural selection.

In Wallace's view God, the Creator, has intervened three times in the history of life. Once, when He created living matter; a second time when, living matter having reached a higher level, He breathed into it consciousness; a third time, when He gave a soul to man (Wallace, *Darwinism*, 1889). Wallace was convinced, as a spiritualist, that space is full of spirits. One, he thought, may have entered a monkey and so brought about his transformation into a man!

Darwin devoted his whole life to the study of the origin of species and natural selection, and after the year 1859 all his published work dealt more or less directly with these topics. Wallace, on the other hand, dissipated his energy. The result of this and of certain peculiarities in his views was that Wallace's influence on the development of biological theory was never comparable with Darwin's.

IV

THE RECEPTION OF THE DARWINIAN THEORY

§ 1. *Darwinism in England.*

DARWIN became known as a scientist—particularly as a geologist—by his *Voyage of a Naturalist on the Beagle*. From 1837 onwards his friends knew that he was endeavouring to formulate a theory of the natural history of Creation. The way for publication was prepared by the appearance of the *Vestiges*. When Wallace produced his paper on a similar theme in 1858, and Darwin published the short account of his own work, the general interest greatly increased. It is true that Darwin had suggested that he was working at the problem of species in the second edition of his *Naturalist's Voyage*, but the very significant change in his point of view had remained unnoticed.

Now all this was to be altered. Huxley, Hooker, and Lyell—all friends of Darwin—prepared the public mind to receive his book, and so it came about that the first edition of the *Origin of Species* was sold out on the day of publication (1859). A second edition appeared a month later, a third at the end of a year, and many after this. Darwin's theory was thus spared the neglect so often the fate of new theories.

This interest did not mean, however, that all men agreed with it. There were many who opposed it, their objections being aroused by the materialistic tendency of the work, by its teaching about natural selection, and by the view there expressed on the origin of Man, rather than by Darwin's ideas on the blood relationship of animals. In *The Times*, the *Saturday Review*, *Athenæum*, *Edinburgh Review*, *London Review*, and many other journals, articles on Darwin's work appeared side by side with controversies on Home Rule and accounts of events in India. Meetings were arranged at which writers, statesmen, and bishops

brought their debating talents to bear on the subject of the origin of Man. Travellers sent particulars from distant lands which seemed to them to confirm or disprove the theory. The question was discussed until a new problem arose to occupy men's minds.

Darwin himself took no part in this newspaper agitation but was interested in the spread of his theory; and the eagerness of his friends to establish the truth of the theory drew from him the following request to Huxley:

'If you write to von Baer, for heaven's sake tell him that we should think one nod of approbation on our side of the greatest value; and, if he does write anything, beg him to send us a copy, for I would try and get it translated and published in the *Athenæum* and in *Silliman* to touch up Agassiz' (*Life and Letters of Charles Darwin*, ii, p. 330).

In his letters there constantly occur such expressions as 'this or that man agrees entirely—partly—with certain reservations', just such expressions as are used by speakers electioneering. Darwin fully understood the demands of publicity, and did not place obstacles in the path of those friends who were defending the theory.

In his work the Creator is pictured as having twice actively intervened in the affairs of our planet. He cites a Church dignitary who agrees with this view. The application of his theory to man is suggested in an extremely 'correct' way:

'Although in the *Origin of Species* the derivation of any particular species is never discussed, yet I thought it best, in order that no honourable man should accuse me of concealing my views, to add that, by the work, light would be thrown on the origin of man and his history. It would have been useless and injurious to the success of the book to have paraded, without giving any evidence, my conviction with respect to his origin' (*Life and Letters*, i, p. 94).

Nevertheless, the book aroused tremendous opposition. The High Church party took offence. A Bishop wrote a strong criticism of Darwin, and Richard Owen and the Duke of Argyll joined the Church party in their opposition.

The Roman Catholic zoologist, Mivart, also criticized the doctrine of Natural Selection very adversely. But Charles Lyell, who was a friend of some of the higher clergy, gradually prepared the way for a more friendly reception.

The anatomist Richard Owen (1809–92)—a supporter of the old idealistic school—rejected the theory, calling the doctrine of Natural Selection 'ancient scholasticism'—not a very suitable comparison. (In the *Edinburgh Review*, 1860.) There was, however, little to be feared from Owen. He had long passed the zenith of his fame, and he was not a clear writer.

George Campbell, Duke of Argyll (1823–1900) was a much more dangerous opponent. A striking stylist and orator, a statesman who was successively Postmaster-General, and Secretary of State for India, he found time, from his duties to Church and State, to study geology and ornithology. A member of the older rationalistic school, he endeavoured to collect evidence of the 'catastrophic' theory from his geological observations in Scotland. Basing his objections on the structure of birds, he rejected Darwin's teaching on the grounds of its materialism and lack of logic. He opposed to it his belief in the ordered plan of Nature. The history of organisms must naturally conform to the fundamental laws of such a reasoned plan.

The Duke analysed Darwin's work on the pollination of orchids. He shows that Darwin, in spite of his objection to teleological explanations, is here looking solely for a purpose in Nature; that he sees in every structure a definite purpose, and explains each feature as the one best fitted for its particular end. He ably takes up this idea of Darwin's. He, too, believes that there is a plan behind every organism (such as Darwin assumed in his teaching concerning homologous parts), and this plan is modified according to reasonable laws and for definite ends. The very same laws hold sway, the Duke would have us believe, in the realm of Nature and in the actions of Man. Neither

Man nor Nature is at the mercy of unreasoning chance—both are subject to definite and rational laws.

In addition to Owen and the Duke of Argyll many other writers opposed Darwin's theories; among his chief supporters were Huxley, Mill, Buckle, Lyell, and Hooker.

Professor Huxley (1825–95), a philosopher, a clear and able writer, a clever debater and a distinguished biologist, was the most successful of those who sought to win acceptance for the theory. He was a man of very independent mind and of great experience. He began his scientific career by working at anatomy and histology, then he turned to palaeontology, and finally came forth as a philosopher. He was considerably influenced by von Baer and by Carlyle. Huxley's scientific achievement, as is so often the case with men who have strong critical faculties, was mainly negative. No well-known biological theory bears his name, but his attacks on older theories are noteworthy. In his anatomical work he rejected the old vertebrate view of the skull, and replaced it by a modern embryological one. In palaeontology he opposed the prevalent ideas of the number of extinct types. In philosophy he rejected Comte, and was critical of any belief in God. He repudiated the doctrine of the equality of men, nor did he share the general enthusiasm for the emancipation of women.

Huxley had greater critical powers than Darwin or Spencer. He had some of the good qualities of both, while intellectually he was much more versatile. He was better read and had a clear and agreeable style. Nevertheless he left behind much less original work than did either of the others, perhaps because of his addiction to controversy. He fought for Darwin, but he did not accept his fundamental law that all living things undergo gradual modification. He supported Herbert Spencer, in spite of the fact that he did not believe in the general equality of men, nor did he think, with Spencer, that morality had developed as the result of the struggle for existence.

He was one of the earliest champions of Darwinism,

and yet he was no complete Darwinist, for he never wholly believed in the phylogenetic scheme. He was no dogmatist, still less did he appreciate concrete formulas or the plastic presentation of any of his ideas. The name *Agnostic*, which he himself invented in 1869, expresses his negative religious views. It fitted the whole trend of his scientific thought.

Huxley used all his experience and all his powers of persuasion in the service of Darwin. He wrote favourable reports of his work, made his teaching known to the masses, gave him his support in the newspapers and at assemblies, and skilfully countered the theological attacks. A critic of Darwinism appeared in the person of Bishop Wilberforce, who obtained his scientific facts from Owen. Huxley pointed out some gross errors in the work of Wilberforce and held it up to public derision, so hitting at Owen. At a meeting of the British Association at Oxford he displayed his ability as a debater, silencing his opponent, the Bishop, by an apt retort. It was merely the triumph of clever repartee, but there were 700 present who saw Huxley's superiority of knowledge and of debating force, and these meant more for the success of the theory than any demonstration of deep truth would have done.

Huxley defeated Owen in a similar fashion in an historic controversy. Owen did not express himself very happily as to the difference between the human brain and that of the monkey. Huxley attacked his statement and proved it to be incorrect. In vain did Owen defend himself by demonstrating that Huxley had misinterpreted his words. Huxley had gained the public ear. The interest in the controversy was so great that a popular song was composed about it.[1]

In England Darwin's theory met with few other

[1] The song is quoted in Huxley's *Life*, vol. i, p. 191. We may quote the words of both parties, so that the reader may judge for himself. Owen wrote 'Their (hemispheres of man) posterior development is so marked (see page following), that anatomists have assigned to that part the character of a third lobe; it is peculiar to the genus Homo, and equally peculiar is the posterior horn of the

important opponents. Men were accustomed to the inductive methods used by him—methods borrowed from political economy and made familiar by books on that subject. All that was now necessary was that those interested in such a controversy should make up their minds about the theory. This done, the matter was ended.

§ 2. *Darwinism in France.*

In France Darwin's theories were very coldly received. Parisian science still lived on the Cuvier tradition, or was under the influence of Comte's Positivism. These emphasized exactness of method, clarity of expression, and the importance of experiment. Claude Bernard and Pasteur were the leaders of biological thought. Both were anti-Darwinists. Among Cuvier's followers, Flourens, de Quatrefages, Milne-Edwards, Brogniart, de Beaumont, Barrande, d'Archiac opposed the new theory. Even later Darwin's teaching was never very fully accepted in France. His books were, it is true, translated into French. Martins the zoologist and Soury the philosopher accepted his teaching regarding evolution, although the latter rather preferred the German version of the theory. Such scientists as Giard, Perrier, Marey, Bert, and popular writers like Dumont, Ferrière, Rosse, and Duval accepted Darwinism, but they never expressed more than a mild scientific interest in his views.

When speaking of France, we must not omit to record the official treatment meted out to him by the French Academy. At the first attempt to elect him as a foreign member, he only received five votes. Later, he was chosen as a botanist, and even at that election the votes of only twenty-six zoologists out of forty were in his favour.

lateral ventricle, and the hippocampus minor which characterize the hind lobe of each hemisphere . . .' (*Journ. Linn. Soc.*, vol. ii, s. 19). These words imply that this marked development is a characteristic feature of human anatomy. Huxley, however, pointed out that Owen is incorrect when he maintains that the above-mentioned parts are characteristically human—'the third lobe is neither peculiar to nor characteristic of Man' . . . &c. (*Nat. Hist. Rev.*, 1861, p. 67). See Owen's defence in the *Edinburgh Review*, v. 240, 1863, p. 558.

§ 3. *Darwinism in Germany.*

✓Darwinism, born in England, found its spiritual home in Germany. Although Darwin, Huxley, Wallace, Francis Galton, and Herbert Spencer lived in England, the majority of the younger scientists went to Germany, to Haeckel, Weismann, and others, to be taught the new theory. This was because it was never taught in England as a scientific system. German scholars were the first to transform this teaching into a 'school of thought'. It was the Germans who gave it a dogmatic and logical form.

In Germany the first discussion of the theory took place early in 1860. In the same year Darwin's book was translated into German by Professor Bronn. The translator's attitude to the theory of the English scientist was significant. Bronn was no Darwinian, but translated the book out of a sense of duty, believing so interesting a work should be familiar in his own country. For reasons already known to us, Darwin only just hinted in his book that his theory was also applicable to Man. Without giving a reason Bronn omitted this reference. That it should not be thought that he wished to testify to his belief in these theories, Bronn added an appendix in which he criticized the views expressed by Darwin.

Bronn's conclusion is extremely characteristic. Having shown why he cannot accept Darwin's theory, and after indicating many objections, he adds that

> 'It is true that even more formidable objections can also be brought against the ordinary theories of Creation, but they are totally different in kind. Creation, being itself supernatural, is not necessarily capable of a natural explanation. It is miraculous and without parallel. It therefore seems to us more logical to retain the old, unscientific explanation. . . . For,' he continues, 'many scientists will adopt the new ideas, and from this conflict of opinion the truth will finally emerge' (*Entstehung der Arten, übers. von Bronn*, p. 518).

This first presentation of Darwin's work was, however, to undergo correction. Bronn's translation was politely

ignored and a new and complete one by Carus was published, which raised no such objections.

Bronn's peculiar point of view was by no means an isolated one; later it appeared again and exerted a much more lasting influence. To understand the fate of Darwinism in Germany we must, however, look back a little.

In the forties there had been very great rivalry in Germany between philosophy and the exact sciences. This really represented a conflict between the aristocratic and the democratic ideal. Philosophy, the queen of the sciences, was in its presentation aristocratic. Philosophers thought that by purely intellectual processes they could deduce general laws for the sciences and for ethics. Hegel considered that philosophical wisdom should dominate the intellectual world. This worship of the intellectual and despising of the practical, this contrasting of the average with the exceptional, is the essence of the aristocratic point of view. The philosophers shared the advantages and defects of that way of thought. They readily attached themselves to the Church and to the temporal powers.

Democratic views were introduced into German science by Vogt, Moleschott, Virchow, and Büchner. They held that knowledge should have its roots in the common life of the people, and should be of practical use. In contrast with most of the philosophers they wrote in an easy style and for the general public, and they spoke disparagingly of philosophy, of the soul, of government, and of other 'unpractical' things. Moleschott's demand that cemeteries should be used for agriculture, since they are such well-manured fields, serves to show the line of thought of these democrats. Moleschott was well known for the eloquence and sincerity of his style.

Vogt introduced into German popular science the style called by the French 'causerie', by the Germans 'Plauderei.' Virchow spoke and wrote in a familiar style and was a strong political liberal. Büchner was prosecuted because of the alleged immorality of his book *Kraft und Stoff*. Vogt was obliged to flee to Switzerland before the forces

of political reaction. Moleschott, reprimanded by the Senate of the University of Heidelberg, resigned his post and migrated to Italy. Virchow was dismissed from his professorship in Berlin, though subsequently reinstated. Such was the state of ferment in the German scientific world when Darwinism burst upon it.

The older scientists, who were also philosophers, rejected the new teaching with indignation, regarding it as an attack on their aristocratic principles. Some became abusive—Burmeister, for example, who strongly objected to the theory connecting the monkey with man; Giebel, the zoologist, declared the teaching 'a chaos of unproved and unprovable impertinences'; Ehrenberg adversely criticized parts of the theory in detail, and then declared the whole to be a 'sick man's fancy', or, at best, an 'interesting romance'. Schimper, the botanist, called it 'the most short-sighted, the stupidest and most brutal theory imaginable, with which a modern buffoon and bearer of false witness could seek to make himself interesting'! The ethnologist Bastian wrote that it was 'an example of mental laziness which had caused a mere stubborn avoidance of the tremendous range of the problems requiring solution'. Fraas, the geologist, declared that the hypothesis of the evolution of Man from an orang 'belonged to that mythological realm where dwells the unicorn'. The theory received equally definite though more mildly expressed criticism from other scientists: Wagner the physiologist, Goeppert the geologist, the embryologists von Baer and Kolliker, Leydig the zoologist, Braun the botanist, and others.

The scientists belonging to the democratic school, on the other hand, welcomed a theory founded on the axioms of John Stuart Mill. Schleiden, although he really represented an older school of thought, was one of the first to accept the new teaching, but he did not publish his reasons for acceptance. Vogt was also a convert. He had previously rejected the idea that animal forms may undergo modification, and had found himself unable to accept

Lamarck's views. He had agreed with von Baer, the embryologist, in opposing the embryological fancies of Meckel and Serres, in which he could see nothing more than a repetition of the hated 'Naturphilosophie'; and he had been a strong supporter of the belief that the varying forms of life were created as they exist without any Divine intervention. Now he became a convert to Darwinism, although he never completely freed himself from the influence of Cuvier's catastrophic theories. Ludwig Büchner now began to teach his ideas about 'Kraft und Stoff' with increased zeal, declaring that man is nothing but a superior monkey. Strauss shared these views. Virchow, too, accepted the theory of Natural Selection, hoping 'that it will be of practical use in every-day life. Its importance for our philosophic and ethical views cannot be over-estimated, since it pictures for us how progress in Time is possible'.

The more moderate followers of the new scientific tendencies also gave their approval to Darwin's work. Du Bois Reymond welcomed it joyfully, calling Darwin the 'Copernicus' of the organic world. He pointed out that this new theory explained the occurrence of those innate ideas about which Leibnitz and Locke had argued; on the Darwinian theory they would be due to inheritance. Helmholtz was convinced that Darwin had succeeded in explaining why each organism is suited for its purpose. In his *Geschichte des Materialismus* Lange completely accepted Darwin's views, and defended them against the criticisms of philosophers. Fechner never freed himself entirely from his older philosophical ideals; but he endeavoured by means of the Darwinian theory to reconcile the two divergent theories of uncontrolled atomic motion, on the one hand, and of an orderly world on the other. He formulated an hypothesis which he called the 'Tendency to Stability', suggesting that the whole universe was originally lawless, and that it is gradually developing towards a more tranquil condition of law and order.

These scientific democrats—Vogt, Virchow, du Bois Reymond, von Helmholtz—thought that they had done

their duty to the new theory in giving it a friendly reception. They assumed that it would now be discussed in university lectures, would become the subject of learned and of popular treatises—in short, would go the way of all scholastic theories. But in Haeckel's hands the teaching assumed a somewhat dangerous form. His views will be treated more fully later: here enough must be said to make the connexions clear.

Haeckel was formerly the pupil and then the assistant of Virchow. In his later years he often used to tell with what enthusiasm he followed the materialistic lectures ('monistic', Haeckel would call them) of his master. The same lectures stimulated Büchner to write his *Kraft und Stoff*. The ideas of Darwin now became linked up in Haeckel's mind with the teaching of Virchow, and he devoted his whole attention to these matters. He accepted with enthusiasm the idea that nothing exists save atoms and their motions. He was sure that Man has descended from the ape. Since these things are true, they must, he held, be generally accepted, and the whole of human life must be ordered in compliance therewith. Haeckel soon began to teach openly that 'the greatest triumph of the human spirit, which is the recognition of Nature's most fundamental laws, must not remain the private property of a privileged intellectual class, but must become the common property of all mankind'.

Haeckel's challenge awakened considerable response. Philosophers, filled with enthusiasm for the theory, and convinced of its truth and importance, gave it publicity by lectures, books, and newspaper articles. Jaeger, Seidlitz, Dodel, Dumont, Büchner, Schmidt, Krause, von Hellwald, Preyer, Rolle, and others became the heralds of Darwinism in Germany.

In 1871 Hellwald became the editor of *Das Ausland*, a paper in which geographical articles were published; and this journal now became an exponent of the Darwinian theory. Krause started *Kosmos* in 1877 for the sole purpose of spreading the new ideas. The proclaimers of the

theory were extremely active. Among them were not only such radicals of the University world as Professors Haeckel (Jena), Schmidt (Strasbourg), Preyer (Jena), &c., but also many non-academic men, as Carneri, Dumont, v. Hellwald, Büchner, Krause, Du Prel, F. Müller, R. Müller, Rolle, and others. The scientific work of these men was very unequal in value, but it would be unjust to them to compare them with the 'popular' writers and lecturers of to-day, who merely express well-worn platitudes in new words. Their work bears evidence of deep sincerity and of a conviction that they are dealing with matters of fundamental importance. This sincerity is very remarkable in books obviously not the productions of first-class minds. Some (e.g. Seidlitz, Schmidt, Carneri) made an earnest attempt to understand the old teaching and to show in what respects it was being supplanted by the new. Others (e.g. Preyer, du Prel, Jaeger) used the theory to develop really new ideas. Others again (e.g. the brothers Müller) spent their time collecting facts in support of the theory.

Anti-Darwinian literature increased in a similar manner. Special supplements, poems, jokes, novels, caricatures, sermons, 'open letters' both scientific and unscientific, and popular books overwhelmed the market. The flood of Darwinian literature was unstemmed.

The spirit of the times, with its ever-increasing materialism and radicalism, was an important factor leading to the general acceptance of the theory. The rising generation saw in the new teaching the only truth. Its opponents were to them mere reactionaries. The younger men heard the conservative teachers still speaking of the 'spirit' in Nature, of the 'thoughts' embodied by each animal type, of the 'mystery' of Creation. The constant repetition of these phrases led the pupils to think that philosophy consisted of mere words, that its day was over, and that nothing new was ever again to be produced by it.

The personal weaknesses of the older teachers also played their part in the controversy. Pedantry, bumptious-

ness, exaggerated ideas of the importance of their own works—all these faults were, as always, but too apparent to the young. In disputes as to the truth of new opinions the old are always at a disadvantage; age signifies reality; youth potentiality. Youth carries the day by its eager hopefulness; age damps expectation. The words of Claudius, quoted by Tacitus, still hold good: 'Omnia patres conscripti, quae nunc vetustissima creduntur, nova fuere.'

Let us see, from some examples, how these Darwinists despised their teachers.

In 1873 Ernest Haeckel wrote to Zöllner:

'It happens by chance that I have known your Leipzig biologists personally for a long time, and can well imagine how these very exact investigators despise your speculative aberrations—that learned man, Leuckart, whose knowledge of zoology is as great as his understanding of it is superficial; the dull uninspired Schenk, who frightened me off botany in my student days; that industrious workman, His, whose industry as a student was only equalled by his narrowness' (the letter appeared as a supplement to Zöllner's *Über die Natur der Kometen*, Leipzig, 1883).

The same thing was happening in England. Huxley wrote to his friend Hooker about Owen, whom Huxley himself had called 'England's greatest anatomist', thus:

'I shall return after the British Association. The interesting question arises, Shall I have a row with the great O. there? What a capital title that is they give him of the *British* Cuvier. He stands in exactly the same relation to the French as British brandy to cognac' (*Life and Letters of T. H. Huxley*, p. 161, vol. i.)

Another time he wrote about Owen to the German biologist Leuckart, thus:

'Particular branches of zoology have been cultivated in this country with great success, as you are well aware, but ten years ago I do not believe that there were half a dozen of my countrymen who had the slightest comprehension of morphology, and of what you and I should call *Wissenschaftliche Zoologie*.

'Those who thought about the matter at all took Owen's osteological extravagances for the *ne plus ultra* of morphological speculation' (*Life and Letters of T. H. Huxley*, p. 163, vol. i.)

What wonder that with such feelings they vigorously contested the established views and pointed out the tremendous importance of the modern ones!

The older democrats were forced to look on helplessly while this new science grew up—a science independent of the Universities and which, although democratic, was certainly not 'liberal' in its tendencies. When the older democrats called themselves 'liberal-minded' they meant to indicate that they were without convictions. The Church, the State, Science were to them purely impersonal things. Hence they were well suited to a university life in which the professors were supposed to play the part of anonymous officials, whose sole purpose it was to teach established views. It was the duty of these officials to cultivate the knowledge given into their care, to increase it, and to make it known to the public; but there must be no expression of any personal conviction regarding this knowledge—the professor must be as unprejudiced as the judge. The fear underlying this idea was that the equal rights of all mankind would be endangered by too much development of individuality. The Darwinists were threatening to upset this equilibrium, and nothing remained but to try to make them conform to the fundamental laws of Liberalism.

Let us try, first of all, to hear the *vox populi*. The 'Liberal' journals, as the *Frankfurter Zeitung*, the *Augsburger Allgemeine Zeitung*, and the *Berliner Nationalzeitung*, were opposed to the theory, and gave the Darwinists ample cause for objecting to their behaviour. The veto of the Universities was also making itself heard. Du Bois Reymond gave his famous lecture *On the Limits of Natural Knowledge* in 1872. He was a professed materialist, but he showed in his lecture that the Darwinian philosophy cannot be followed to the bitter end, since psychological phenomena must be excluded from it. The materialists objected to the content of the lecture, and publicly pointed out its shortcomings. It had, however, a lasting influence.

On another occasion, in 1876, du Bois Reymond directly attacked the ideas of Haeckel. He remarked pointedly that his genealogical tree is to the exact scientist about as valuable as is Homer's genealogy of his heroes to the historical critic.

Finally Virchow—the old liberal—played his part in destroying the last links that bound together the old and the new views of science. Virchow takes an important place as founder of a new school of thought in medicine. Before him medical practice was dominated by the so-called 'humoral pathology', which attributed all diseases to changes in the fluids of the body. Virchow replaced this view by one ascribing disease to cells which had undergone pathological changes. For him, and for many after him, pathological anatomy became the basis upon which all medical work rests. This theory, still important, was then in its heyday, although the bacteriology of Pasteur and Koch was threatening its pre-eminence. The importance of this bacteriological theory of disease was later greatly increased by the growing knowledge of toxins and antitoxins, on which is based a view of disease that has some affinities with the ancient humoral pathology.

The reputation of Virchow was world-wide. He had, moreover, an accepted position as an anthropologist, and he was a member of the Prussian Reichstag. As politician and as scientist Virchow was a typical 'liberal', a man not disinclined to adopt Voltaire's famous axiom, 'it is sufficient if only my tailor believes in God'.

Let us examine, as an example of Virchow's method, his famous *Gesammelte Abhandlungen zur wissenschaftlichen Medizin* (1856). When it appeared it filled Haeckel with enthusiasm for its 'breadth of vision', its 'ideas at once philosophic and scientific', its 'critical and yet strongly monistic point of view'; it also was the source which inspired Büchner's materialism. The work deals with the usual problems of academic science, but the first chapters have stimulating titles—*On the Nature of Man*, *On Philosophy*, *On Science*, *On Life*, and so on, and they treat these

problems in an original way. The book may be summarized thus:

'It presents the harshest materialism imaginable. For Virchow, however, this is hidden behind the confused tangle of ideas he connects with such words as Matter, Force, Causation, Inertia. These words are connected, even in the realm of Natural Science, with quite definite ideas, and they cannot be separated from those ideas without bringing absolute confusion into the whole of scientific phraseology' (Schleiden, *Über den Materialismus der neueren Naturwissenschaft*, Leipzig, 1863, p. 49).

Thus Schleiden described Virchow's style. The reader to-day will hardly agree with these strictures, but will ask why Virchow philosophized as he did, when, to judge by the tone of his writings, he believed philosophy to be so completely negligible.

In the year 1877, at the annual meeting of the Society of German Scientists and Physicians at Munich, Virchow openly opposed Haeckel, who had spoken most enthusiastically of Darwinism. Reminding his hearers of the fundamental views of 'his honoured master' Virchow, Haeckel claimed it as an irrefutable physiological fact that our inspiration depends upon the form of our nervous system. Since the nervous system is built up of cells, it is the cell (he held) that is the foundation of our psychic life. Our scientific ideas, therefore, point incontrovertibly to a 'cell-soul'. Still following the ideas of Virchow, he continued, and remembering that cells are built up from atoms and molecules, we deduce that these, too, must possess souls. The attractions and repulsions of atoms represent their loves and their hates. Their movement is their sensation, and it is at this point that the work of the psychologist begins. But if this is the incontrovertible truth, it is not enough merely to affirm it. We must also follow it to its logical consequences; we must introduce the theory into our schools as the fundamental principle upon which all our teaching is to be reorganized. The teaching of morality and of religion must also be reformed. The evolutionary theorist will base his ethical teaching on

that natural law which, in the form of blind instinct, dominates the animal world, and which is older than any system of morals. Away with Revelation! We will replace this by the recognition of the laws of evolution.

This bold speech supplied the keynote for Virchow's lecture. He spoke first of the struggle for freedom in the expression of scientific opinion. 'The mere holding of this assembly and the speeches made at it sufficiently proves that science has won complete freedom. We must retain this privilege. Moderation, and the relinquishing of personal predilections, will be necessary if public opinion is to continue favourable.' In a stimulating speech he then proceeded to point out the boundary which divides science from mere speculation. With biting irony he criticized Haeckel's views of soulful cells and of men descended from monkeys. So long as such ideas were unproven we should refrain from teaching them in our schools, where only established scientific views should be imparted. Problems were subjects for research, not for instruction. Only when the theory of evolution became certainly established dare we base upon it our whole view of the world, of society, and of the state. And we must do this then, in spite of one very questionable feature of the whole theory—its socialistic tendency.

We must remember that the lecture was given in 1877, when the socialists were held by all other parties, even by the liberals, as a danger to the State, and were being kept down by the most drastic methods. To the impartial observer of to-day two questions occur: Why did Virchow interfere in this debate on Darwinism? And—Was the Darwinian theory really so near to socialism?

By this time it was generally recognized that in Germany Darwinism represented, if not a new religion, at least a new faith. The partisans of the Church and of the new scientific theories were discussing ideas which were, to them, of fundamental importance. Virchow favoured neither Haeckel nor the Church; he was a

thorough 'liberal',[1] and as such had no sympathy with any conviction. As a scientist, seeking the truth, he had the right to ask Haeckel for proofs. But the public does not recognize the existence of any such right. Probably no one was ready to believe that Virchow had been moved to deliver this lecture simply by a love of truth. Both conflicting parties—Darwinists and clericals—considered that he had recanted his earlier views. The Church papers praised him on this account, while the Darwinists looked upon him as antagonistic to the evolutionary theory.

Regarding the second question, the evolutionists Haeckel, Huxley, Darwin, Schmidt and others declared that the ideas of the social democrats could not logically be deduced from their theory. Virchow was certainly not of this opinion. For him Darwinism spelt dogma, fanaticism, and he saw the same fearful force in socialism. The might of this conviction could only lead to one thing in his eyes—to Revolution. He saw, further, that the socialists really had definite leanings towards the doctrine of Natural Selection. The connexion between the two was very like the connexion between Darwinism and liberalism. Virchow looked at the whole question from the 'liberal' point of view. We see this in his naïve assertion that men must only teach the evolutionary doctrine when they were certain of it. As if the Darwinians—as if Haeckel—had any doubt concerning it! They would have sworn by all they held sacred that it was true; just as their clerical opponents tried by solemn oaths to strengthen the opposite view.

Haeckel answered Virchow's speech in his book *Free Science and Free Religion* (1878), perhaps the best piece of polemical literature produced by the whole controversy. Haeckel knows that the theory of evolution is true, and 'It never will be proved if those proofs which we already possess do not suffice'. He must therefore teach it, for 'He who knows the truth and does not declare it is indeed despicable'. There is no such thing, Haeckel holds,

[1] Translator's note. The word 'liberal' is used all through this translation in its German sense.

as 'objective science', for there is no sharp boundary dividing fact and theory. All teaching must inevitably be coloured by the personal convictions of the teacher. Virchow's own teaching was itself entirely dominated by his own point of view, as Haeckel himself had found when he was his pupil. By his lecture Virchow had simply thrown his influence on to the side of the Church.

Haeckel also dealt quite frankly with the relation between science and politics. Every new philosophy has its practical aims—and so every new philosophy must inevitably influence political thought. Darwinism is, however, an aristocratic rather than a democratic creed, since the whole theory rests on the belief in the inequality of man. Further, we must not forget how little our practice conforms with our theory. Do we not see this every day in the cleft between Christian teaching and the practice of Christendom?

But despite Haeckel's eloquence the tide had begun to flow against Darwinism, and Haeckel's apology did not hold it up. Virchow had achieved his end.

A few months after his speech there were two attempts to assassinate the Kaiser. One was made by a workman, the other by a Doctor of Philosophy. The socialists were blamed for these crimes, and they were used as political capital. Clerical newspapers did not hesitate to blame Darwinism. The Government asked the Reichstag for special power to suppress the Social-democratic party, and obtained it. The request made a dissolution necessary, but they obtained the right from the new Reichstag. These measures were undoubtedly a blow to the Darwinists.

In 1878 the Prussian Minister of Education said in the Landstag, during a debate on a new Education Act, 'Do not think that this law would allow notorious Darwinists to be appointed as science teachers in our secondary schools' (Mittleren Unterrichtsanstalten). Virchow not only did not oppose but he actually voted for the reprimanding of one Herman Müller, a secondary school teacher. Müller was a well-known botanist and believer in evolu-

tion, who had tried to introduce the theory into his school teaching.[1]

In these circumstances Darwinism could not flourish; Haeckel retained his opinions, showing how deep was his conviction. A few workers attempted to defend the evolutionary theory against the charge that it led to Socialism, but no one except Haeckel sought to show how wrong was Virchow's endeavour to make a fundamental distinction between 'teaching' and 'research'.

We may see the results of this discussion in *Cosmos*—a paper which was in favour of Darwinism. This paper had for its motto the defiant phrase: *Impavidi progrediamur!* Yet, a year after the lecture in 1878, it thought it necessary to publish an editorial *Towards Peace*. In this Darwinism was upheld, but its supporters were told 'to guard the religious sentiments of the people in all their simplicity and purity; for the masses pay little attention to constructive ideas but rather regard to destructive views, refutations and disavowals'.

[1] H. Müller published his defence in the pamphlet, *Die Hypothese in der Schule und der naturgeschichtliche Unterricht in der Realschule zu Lippstadt. Ein Wort zur Abwehr und Rechtfertigung*, Bonn, 1879. Another case of a 'disciplinary' punishment as the result of Darwinist teaching is given in *Cosmos*, vol. iv, 1878–9, p. 357.

V

CRITICISM OF DARWINISM BY THOSE STILL IN FAVOUR OF THE OLDER SCHOOLS OF THOUGHT

ALTHOUGH the problem of the genetic relationship of living organisms was in every one's mind, Darwin's answer was unexpected. The old 'Naturphilosophie' was dead, but many people still fully believed in a rational plan in Nature and in God.

Men of science in general saw the ever-growing materialism but for the most part rejected it in disgust. Both philosophically and scientifically they held themselves superior to Büchner and his friends, with their meticulous dilettantism.

They were all awaiting a new light on the question of development, and behold! it came from Darwin; but it came in a manner new to science. He offered neither morphological argument nor physiological experiment nor profound speculation concerning the nature of life, but, in the place of these, an enormous mass of quotations from books of travel. He himself belonged to the hated materialists, and deprived the older thinkers of their dearest belief—their belief that Nature is rational. Is it surprising that so much obloquy was heaped on the new theory and its exponents?

But yet the movement increased, and the older thinkers, seeing the uselessness of opposition, began to retire from the contest. Only one or two of the bolder spirits tried to point out that they had already expressed views similar to those of Darwin but without Darwinian materialism. We will consider some of these:

Louis Agassiz (1807–73), a Swiss by birth, was a man of science and a traveller who had marked American sympathies. While still living in Europe he resolved to compile an exhaustive treatise on the fossil fishes. In America he obtained financial support for his plan, and entered on a period of widespread scientific activity.

He contemplated a very full *Natural History of the United States*, and wrote an *Essay on Classification* (1858), which was to serve as an introduction to it. In this he gave expression to his philosophical views. People were expecting something very remarkable. Agassiz was not only a palaeontologist and anatomist, he was also a well-known embryologist and geologist. Further, he had made a name by his study of deep-sea fishes. But the work was disappointing. It was perhaps comparison with Darwin's work that belittled it. In Darwin's book were facts and new views concerning Nature; in Agassiz' only generalizations, reminiscent of ancient philosophical arguments, and illustrated by well-worn examples.

Agassiz believed that there is purposeful guidance behind the universe, which the development of living organisms can partly reveal. This purpose is the manifestation of that fundamental idea which finds expression in the manifold types of animal organization.

In the later editions of his book Darwin challenged Agassiz' views. They served, as it were, to illustrate the antithesis of his own, and, as so often happens in these cases, he looked upon every valid objection to his opponent's ideas as an added proof of his own theory. The essence of Agassiz' teaching was that a species is not only defined by its anatomical, but also by its physiological, geographical, and other characters, and that the species is constant in all these respects. Darwin, following his usual method, did not criticize this assertion, but attacked Agassiz' belief in a Divine Plan, in twenty acts of Creation—his idea that each species came into existence as a number of individuals, which appeared simultaneously in various parts of the world. He showed that such words as 'God' and 'Creation' explain nothing. Among other men of science who attacked the teaching of Agassiz was Haeckel. He gave it less consideration than had Darwin, regarding it merely as unscientific theology, and hardly worthy of the earnest attention of a man of science.

In his *The Anatomy of Vertebrates* Richard Owen criti-

cized Darwin's views. He did not object to the assumption that present-day forms have arisen from extinct ones, but could not accept a theory in which 'Chance' plays so great a role as in the idea of Natural Selection. He believed in 'an inborn tendency to deviate from the parental type, and that these deviations have an effect after a sufficiently long period'. He obtained little support. When Darwin came into prominence Owen's fame was already on the wane, and his faults of personal character mitigated against his obtaining a hearing. Owen and Mivart were among the very few whom Darwin treated with contempt.

St. George Mivart, an English convert to Catholicism, published several works opposing Darwinism. He regarded the idea of Natural Selection as a false and brutal conception which owed its success largely to its anti-clerical bias and to its apparent simplicity. He himself believed that an inner spiritual force was the cause of development; and he named his theory 'Psychogenesis'.

The philosopher has, according to Mivart,

> 'the strongest possible ground for affirming that in the process of evolution we have evidence of the activity of a Great First Cause, ever and always operating throughout Nature in a manner hidden from the eye of sense, but clearly manifested to the intellectual vision of every unprejudiced mind. This action is that secondary or derivative creation, *per temporum moras*, distinguished by St. Augustine from that instantaneous primary creation which took place, *potentialiter atque causaliter*, in the beginning. Thus a belief in 'evolution', far from leading to a denial of 'creation', distinctly affirms it'. (Mivart, *The Cat*, p. 527.)

In England considerable attention was paid to Mivart's objections to the Darwinian theory; on the Continent they had no influence.

H. G. Bronn, at the end of his translation of Darwin's work, gave a criticism of the idea of Natural Selection based on his own views of morphology. His whole attention was focused on the geometry of the living body. He asked why one plant has lancet-shaped and another oval

leaves; why one species has five stamens, another only four; why one organism finds this structure useful, another the exact opposite. Bronn pointed out that the struggle for existence does not explain these things. He had searched Darwin's book in vain for any proof that such things are inevitable.

Among the supporters of the earlier views was Albert Kölliker, a very able embryologist and histologist. He pointed out that Darwin describes animals as if the only standard by which we can measure their structure is fitness for the struggle for existence, and, as if therefore, the one is better adapted for the fight, the other less so. This view, he said, is incorrect.

'Every organism is perfectly adapted to the purpose it is to serve, and the reason for this perfection is not to be sought for in the organism.' . . . 'The idea that each organism exists for one definite purpose only, rather than that it embodies a general Thought or Law, gives a very one-sided view of creation. It is true that every organ, every organism, has its purpose, but that immediate purpose is not the only reason for its existence.' (Kölliker, 'Über die Darwinsche Schöpfungstheorie', *Zeitschrift für wiss. Zoologie*, 14. 1864.)

Kölliker did not doubt that there is a genetic connexion between different forms: but according to his view evolution has occurred in jumps. He thought that an organism might suddenly have laid eggs from which a new species arose—probably under the influence of external conditions; or that the change might have taken place as does metamorphosis in the insect world, where the egg produces a larva, the larva a sexually mature individual unlike itself; or, finally, that the origin of new species might be analogous to the origin of the different kinds of bee, where one queen can produce workers, drones, and new queens.

Von Baer also took part in the discussion. In his youth (1828) he had objected to Lamarck's views. With remarkable insight he had then pointed out that Lamarckism was identical with Meckel's theory, and that on both views animals were looked upon merely as 'rough drafts' of man. Nearly sixty years had passed since he expressed

these views, and both philosophic and scientific thought had undergone many changes since he was the leading biologist. To show that he could use new material to support old truths, he published a work in which he cited various new discoveries which, in his view, upheld his old theories.

Von Baer rejected the idea of selection, nor did he believe that Nature is merely a blind mechanism. He contrasted this view with his old doctrine of the purposefulness of every event. There is no need to ascribe the similarity among animals to a common origin—it rather proves the similarity of the animal-creating forces. It is illogical for the new teaching to assert that the idea of species is an artificial one, and yet to describe species; there are no grounds for relating men to monkeys.

Baer believed in evolution, but was convinced that the Creative Force had been far mightier in the first epochs of the living world than in our time. He thought this force had continually diminished, and perhaps was already exhausted. He believed further that the higher forms of life might have arisen by spontaneous generation, and he held firmly to the view, which he shared with Kölliker, that species arise by leaps.

Baer's criticism of the Darwinian theory had no effect. Darwinians ascribed his want of understanding to senility, and little attention was paid to his writings, even by the opponents of Darwin. His friend Teichmüller, the Dorpat philosopher, agreed with him, but this advocate aroused even less attention.

The position of Michaelis, who was among the opponents of the theory, was a quite peculiar one. Originally a Catholic priest, he rejected the doctrine of Papal Infallibility, and founded with Döllinger the sect of 'Old Catholics'. In addition to his theological polemics he published a series of treatises on Natural Philosophy, in which he rejected Darwin's principles, and pleaded for the Platonic view of Nature. These works impress the modern reader curiously. He seems to know few scientific

facts, and his writing is often obscure. Few had enough patience to read his works to the end. But Michaelis was very much in earnest in his opposition to Haeckel. He opposed the fundamental idea of the newer thinkers—that all complex objects must be explained by reference to simpler ones. He thought we must begin with the knowledge of man, in order to understand the rest of Nature. For Nature is only the expression (not even the development) of one idea, which reveals itself everywhere—in the solar system, in the mineral, plant, and animal worlds. We should not search for evolutionary trees, but for ideal types. Michaelis regarded as such central forms or types the moss among plants and the mollusc among animals.

According to him the differences between the two are determined by the difference in their direction of growth; the plant's axis is vertical—it grows with one end pointing towards the earth's centre, the other towards the centre of the solar system. It is therefore more nearly related to this than is the animal which has its axis horizontal. In man the original form of the plant is repeated in a fully developed animal body. Michaelis often speaks of a 'struggle for existence', but he uses this expression in an idealistic manner. In the flower, for example, he conceives the original plant nature (a bud which would tend to elongate) to be struggling for its existence with a sexual nature which is tending to overthrow the original plant form.

With such ideas—which were merely late offshoots of a philosophy already relegated to oblivion—Michaelis did not influence the Darwinians. They could not understand him and made no effort to do so. He is never quoted in scientific writings.

In France Darwin was ably criticized, not only by Flourens and d'Archiac, but also by de Quatrefages. The latter writer pointed out how Darwin always speaks of the possibility rather than of the necessity for his conclusions, and how often we could arrive with equal probability at exactly opposite views. Further, he pointed out that Darwin makes too much of the incompleteness of the

geological record. Our knowledge of extinct animals is enough to show that in the history of life on our earth there has never been the chaos demanded by the theory. He also rejected Darwin's idea of species, his references to chance, &c. Quatrefages' criticism is valuable even to-day, and yet it seems to have been much neglected by later evolutionists.

The above criticisms were all directed against special aspects of Darwin's teaching. An attempt to discuss and to refute the whole theory was made by the German botanist Albert Wigand, who issued a three-volume work dealing with it.[1] This remains, even to-day, the most complete on the subject, and although issued over fifty years ago contains practically all that can be said against Darwinism.

Wigand explains that Darwinism is much more than a theory; it is a frame of mind which dominates thought, a resuscitated 'Naturphilosophie', in which the terms 'Polarity', 'Totality', 'Subject', 'Object' are replaced by such as 'Struggle for Existence', 'Inheritance', 'Selection', and so on.

Darwinism is as far removed from science as is a fairy-tale from history. It has no programme, no method, no logic. He asserts that the mode of origin of new forms is quite beyond human understanding, for in no circumstances can differences between phenomena be explained by a general principle. Neither the law of gravity, nor any such general law can enable us to understand the differences between the planets, the minerals, the elements, between light, warmth and electricity; nor can the differences between animals be explained. Such differences can only be experienced—they cannot be divined. Wigand shows further how Darwin disguised the difficulties of his theory by the amassing of facts; he points out the defects in Darwin's conceptions of species, of heredity, of fitness and so on.

[1] Wigand, *Der Darwinismus und die Naturforschung Newtons und Cuviers*, Braunschweig, 1874–5.

All these are valid objections and are recognized to-day. Yet even Wigand's criticism was faulty. It is almost entirely directed against Darwin's logic, but the Darwinians were not interested in discussions of method or of philosophy. Wigand, too, though a good critic of the faults of his opponents, was quite unable to formulate any ideas of his own. He opposed Darwin's teaching of expediency, and then, to justify the idea of purpose, he postulated a God who is a simple immaterial Being standing outside Nature, and determining its purpose.

In opposition to Darwin's idea of descent with modification, he formulated his own theory of descent.[1] He assumed that there were in the beginning primitive cells, which contained the essence of both the plant and the animal. From these arose plant and animal cells; the plant cells were subdivided into those of Thallophytes and Cormophytes; these again produced cells of narrower range, till finally the original cells of the narrowest groups—of the species—were formed. From these plants then developed. Wigand himself apparently came later to consider this theory as of minor importance.

Many other workers raised similar objections to Darwinism; Leydig, the zoologist, for example, who rejected Darwin's idea of the working of chance, and urged scientists to search for the laws governing evolution; Alexander Braun, the botanist; Baumgärtner, the zoologist; Wagner, the physiologist; Huber, the philosopher, and many others.

To-day, when we look back upon these old criticisms of Darwin's views and the answers given by his supporters, it soon becomes obvious that here are two opposing worlds of thought speaking different languages. Darwin's aim was to *describe* Evolution; his opposers affirmed that he did not *understand* it. Darwin sought for *causes*; they for *motives*. For him evolution supplied a *chronicle* of the universe, full of the smallest incidents; they affirmed that

[1] He develops this theory in his treatise *Die Genealogie der Urzellen als Lösung des Deszendenzproblems*, Braunschweig, 1872.

he had not discovered behind the world's development any great *plan*. By the word 'Law' he denoted the probability with which a definite conclusion can be deduced from known events; for them Law denoted that eternal and changeless Law which gives meaning to the manifold variety of nature. It was thus that misunderstandings were caused among both the older and younger schools of thought. The Darwinists were very much surprised when men like von Baer, Kölliker, and Braun rejected the new teaching, although the idea of development was not new to them. Unable to understand this opposition, they suspected that these opponents were denying their earlier and better convictions for fear of the consequences. Lyell himself did not escape this suspicion, for in his work *The Geological Evidences of the Antiquity of Man*, although he showed that the earth was probably inhabited by man before the Ice Age, and did not reject the idea that Man may have come from a monkey-like ancestor, yet he always opposed the materialistic tendency given to these ideas by Darwin. It is significant how distasteful to the older generation was that youthful courage which led the younger men to follow their ideas to their logical conclusion, and to defend them publicly.

In his own school Darwin himself was certainly the best controversialist, and in the later editions of his book he tried to answer the scientific objections to his theory which had been brought forward by Agassiz, Bronn, Mivart, Nägeli, and others. He frequently misunderstood their objections, however, and answered them only too often with the words 'We are as yet profoundly ignorant of this'.

Huxley's clever reply to Kölliker missed the point. Kölliker, he said, feels that the theory lays too much stress on purpose; now it is well known that Darwin has banished the idea of purpose from natural science. But this artifice is too simple; it is quite obvious to the reader that the word 'purpose' has different meanings in the two sentences. Huxley's ideas were not, in fact, as different

from Kölliker's as might be thought. Though a loyal friend of Darwin, he by no means blindly accepted all his teaching. In particular, he did not wholly agree with the idea of Natural Selection, but preferred the hypothesis that new species arise from older ones by 'transmutation without transition'. He gave a very non-Darwinian analogy from chemistry—one combination passing into another, there being no intermediate forms which link the two.

'In an organic compound, having a precise and definite composition, you may effect all sorts of transmutations by substituting an atom of one element for an atom of another element. You may in this way produce a vast series of modifications; but each modification is definite in its composition, and there are no transitional or intermediate steps between one definite compound and another. I have a sort of notion that similar laws of definite combination rule over the modifications of organic bodies, and that, in passing from species to species, *Natura fecit saltum*.' (*Life and Letters of Thomas Henry Huxley*, vol. i, p. 173.)

It is true that these words were written some months before Darwin's book appeared, but when this was published Huxley, in praising it, pointed out that Darwin had increased his own difficulties by rejecting the idea of a *saltus* in organic Nature.

Kölliker was a friend of Huxley, and there were others who fared worse than he did. The French had little sympathy with the idea of Natural Selection, and so it was simply assumed that their science was decadent. They did not, in fact, produce nearly as much work as did the Germans. We cannot wonder that opponents whose intellectual calibre was not very great received little attention; but even Wigand's fine work was ignored or treated with contempt. Dodel-Port considered it unworthy of notice. Vogt joked about the thickness of the book. Krause wrote that it would not be read even by Wigand's friends. In his review of the Darwinian literature Seidlitz said that it was 'the most valuable among the anti-Darwinian writings, for it costs four crowns'!

Zöckler's book on the *History of the Relation between Science and Religion* (1877) contains a full and objective criticism of Darwinism from the theological point of view. If we may judge from the Darwinian literature, it was hardly realized that such a book existed. Is this to be wondered at? Even in the nineties it was said that Kölliker had seriously damaged his reputation by his criticism of Darwinism. Such is the power of public opinion.

Apparently Darwin himself did not feel certain of his victory. Outwardly he had conquered along the whole line. Enemies were silenced or in retreat. Yet the criticism had not been without effect. Very striking, in the midst of all this apparent success, are the words he wrote in 1871. Speaking of the objections to his theory he said:

> 'If I have erred in giving to Natural Selection great power, which I am very far from admitting, or in having exaggerated its power, which is in itself probable, I have at least, as I hope, done good service in aiding to overthrow the dogma of separate creations.' (Darwin, *The Descent of Man*, p. 61.)

VI

EVOLUTIONARY PHILOSOPHY AND ETHICS

THE Romantic Philosophy was not suddenly overthrown. Its decay can be traced step by step from Hegel through Feuerbach and Strauss, to Schleiden, Lotze, Fechner and Lange, and it finally reaches its lowest point in exact science. The desire to philosophize remained, as did the public philosophical institutions, but these had to adapt themselves to the spirit of the times. To do this philosophy had to forgo her ancient privilege; she could no longer prescribe the laws of thought. To her fell in return the glorious and honourable task of examining that foundation which is common to all the sciences; of investigating those things which science leaves untouched because held beyond investigation. Attention was now directed to the history of philosophy. Moreover, an interest in ethics arose, and there was an endeavour to reconcile uncertain 'faith' with certain 'knowledge', to examine the nature of religion, and so on.

There was a great contrast between the subject-matter of this philosophy and that of her proud forerunner, which had reigned since antiquity. Modern philosophy dealt only with the more doubtful forms of knowledge, nor was there any field of knowledge where she reigned supreme. She was ever at the mercy of scientific criticism. As a consequence the philosopher was no longer a specialist, for having to make use of the results of all the sciences he was at home in none. The exact scientist thought of him as of little account—as quite without the right to meddle in the scientific domain. Philosophy and science were completely estranged.

This fall of the 'greatest of all the sciences' had its good side. Philosophy became democratic, while naturalists, on the other hand, freed from the fetters of philosophy, were able to investigate the subject for themselves—they became philosophers. When we speak of scientific philosophy

we are generally referring to the fact that Helmholtz wrote about Kant, Huxley about Hume, and so forth. But in such cases the scientific specialist, as such, was only in indirect relationship with philosophy. Greater importance should be attached to those cases where the scientist, almost without knowing it, ventured on philosophic ground; those cases, almost neglected by the philosophers, where, as the necessary result of his discoveries, he was led to formulate some universal law. To this type of philosophy belong Darwin's ethical, Huxley's and Haeckel's sociological views; Mach's, Darwin's, and Cuvier's scientific methodology, &c.

It is not clearly recognized even to-day that a new philosophy has arisen, one more natural than the older systems. We forget that, although a Darwin or a Haeckel did not fill two chairs, one of Science and one of Philosophy, yet their science cannot be separated from their philosophy. We must remember, too, that the ultra-modern reaction against science does not represent a return to ancient abstract metaphysics, but that we have here the beginnings of a philosophy founded upon natural science; the works of Mach, Driesch, and Ostwald furnish a proof of this.

Herbert Spencer (1820–1904) is a typical example of the philosopher whose system is based on natural science rather than on his own inspiration. At first an engineer, and then an editor, he lived finally as an intellectual of independent means. With true English patience, he built up a new evolutionary conception of the world based on biology. He began his work before Darwin's time, at first in scattered articles, then in a work which was to include all that we know about life. The book is very dull, but is simply written. The ideas it contains are not deep, but they are sound and typically English.

This is not the place for a detailed examination of Spencer's philosophy; we will only note certain special characteristics of it. Spencer believed in God very much as Darwin did, who thought it idle to dwell on that sub-

ject, since no certainty could come from such thinking. It is also unnecessary; man can do his duty without any belief in God. And yet Darwin did not want to play the atheist and attack old beliefs. That was not his view of his duty to society.

Spencer expresses practically identical ideas. He does not reject religion. Each system contains some fraction of the truth; it is difficult to say how much, for the real essentials of religious belief are unknowable. In practice, however, Spencer held that religion is something lower than science, suitable for people of small intelligence. He himself, with his greater knowledge, need pay little attention to these unknowable things.

The crowning feature of Darwin's philosophy is the idea of Natural Selection. Spencer discovered a still more fundamental cause of phenomena—indestructible matter in unrestrained motion. Matter in motion leads directly to evolution, and this is

'An integration of matter and concomitant dissipation of motion; during which the matter passes from an indefinite, incoherent homogeneity to a definite, coherent heterogeneity; and during which the retained motion undergoes a parallel transformation.' (Collins, F. H., *An Epitome of the Synthetic Philosophy*, 1889, p. 47.)

Life is only a particular combination of matter and motion. Living substance owes its 'life' to complicated and very unstable compounds; the essence of life is adaptability. Power of adaptability is a measure of progress. The broadest and most complete definition of Life will be: The continuous adjustment of internal relations to external conditions. The amoeba, the multicellular backboneless amphioxus, the monkey, the man, a pair of savages, civilized society—all these, according to Spencer, illustrate the stages by which life adapts itself to its environment. The most fundamental living processes are growth, differentiation during development, the simple vital functions, adaptation, the separation of life into individuals, reproduction, inheritance, and variation.

For Spencer, phylogeny only represents one aspect of the evolution of the world. We must believe in it, since the other alternative—Creation by God—is scientifically inadmissible. Spencer assumes, as does Darwin, that evolution is actually in progress in the living world, and his reasons for this belief are similar to Darwin's. It follows from the fact that we can formulate a 'natural' system of classification, from the resemblances between different animals, from embryology, from the facts of geographical and geological distribution. Spencer further assumes that this development is accelerated by external circumstances, climate, for example, and the living environment, and also by inner conditions (as the 'lability' of the undifferentiated homogeneous condition).

He gives moreover the outline of a genealogical tree for plants and animals, classifying them according to their form and function.

Looking through Spencer's *Principles of Biology*, and reading his monotonous questions and answers, we are not surprised that he was proclaimed in his own day as a universal genius. Here are examples of the questions which he felt able to discuss and to attempt to answer:

'Why should the growth of every organism be finally arrested? Why should not all organisms, when supplied with sufficient materials, continue to grow as long as they live?'

'Does Life produce Organization, or does Organization produce Life?'

'What are the conditions under which Genesis takes place? How does it happen that some organs multiply by homogenesis, and others by heterogenesis?'

'Why do offspring resemble their parents?'

'What is the original cause of this differentiation? (of tissues in stems, petioles, &c.). Is it possible that this modification of cell-structure which favours the transfer of liquid towards each place of demand, is itself caused by the current which the demand sets up? Does the stream make its own channel?'

'Reference has been made more than once to those thickenings that occur where skin is exposed to unusual pressure and friction. Are these adaptations inheritable? and may they, by accumulation

through many generations, produce permanent dermal structures fitted to permanent or frequently recurring stress?'

'How came animals to develop a liver?'

'What is the origin of a nerve?'

All these questions and hundreds of others are formulated by Spencer, and to all he attempts an answer. This was a peculiarity of Spencerian philosophy, and typical of the school of thought which arose under his influence. They had an answer for every question. The thing which you ask is simply the result of certain mechanical, chemical, and physical factors, he says, and then he offers his explanation—the one which seems to him the most likely in the given circumstances. He invents it, he does not deduce it from experiments or observations. It is true that Spencer did pursue definite biological studies, but these hardly bore any relationship to the substance of his explanations—and his explanations far exceeded the range of his observations, both in quantity and in quality.

All the above questions, cited from Spencer, are so difficult that they can only be approached with the expenditure of the greatest intellectual exertion, and by an observer with a very deep insight into biological problems. Suppose, for example, it is desired to throw some light upon the origin of nerves. What a mass of observation and experiment, what a searching of the literature, what an amount of deep thought would be necessary! The problem is so vast that there are few investigators who would care to-day to attempt its solution. Imagine how differently these questions would be attacked to-day, for we now realize that this relation between life and structure is one of the deepest and most obscure problems of modern philosophy. Spencer formulated the question and answered it, as he answered all similar problems, in a few pages, even in a few lines!

This method reduces to despair those who examine such works in search of philosophic truth. Yet it was the method of the whole of Darwinian biology and scientific psychology. Spencer was not the only one who used it.

It is a logic which assumes that everything is already known. It acknowledges no mystery; it is surprised at nothing in the world. It follows the maxim *nil admirari* with an almost impossible consistency.

Further, the very strong conviction existed that this method had been from time immemorial *the* scientific method. When the reaction against science began, people very justly complained of its aridity. How could it satisfy our desire for truth? It was then seen that this superficial evolutionary method, which can explain everything in advance, is not characteristic of all science. Those investigators who believed in the mystery—the unfathomable depths of Nature—were the greatest investigators. When Newton looked at Nature as a great sea on whose shore he was only collecting scattered pebbles, he gave voice to a scientific spirit very different from the Spencerian one. The fact that great investigators like Kepler, Newton, Swammerdam, Pascal, van Helmont, Johannes Müller were mystics, or became such, that they abandoned the hope of understanding by taking thought, and simply surrendered themselves to their inspirations—all these are manifestations of a very different science from that which alleges that there is no mystery in Nature.

For Spencer, as for Darwin, the fundamental principle is: 'There is no absolute Reality, everything is a "result"'; the species is the result of natural selection, and this follows from the struggle for existence. This, in its turn, arises because of the general properties of living matter. These in turn are the results of the chemical and physical constitution of matter. These follow from the motion of their atoms. And even this motion has no absolute value, but is the product of subjective sensation, which is again only a result—of what?

Spencer's truths and falsehoods can be summarized as follows:

(*a*) Belief in God. We know nothing of His nature, nor of the reason for His existence. He is probably not concerned with our world. The belief in Him is very likely

only the result of man's astonishment at unusual occurrences, an astonishment which has become fixed by inheritance. Nevertheless, believe!

(*b*) Evolution went on through millions of years in infinite space. Every condition, as it arose, was the 'cause' of the ensuing one. But neither time, nor infinite space, nor the causal connexions between phenomena have any absolute existence; they are only ways of thought impressed on men by the inheritance of certain chance habits. Nevertheless, you must believe in the millions of years, in infinite space, in necessary causes!

(*c*) Be moral! It is true that your love for your nearest and dearest has arisen during the rude fight for life, and that the law 'An eye for an eye, and a tooth for a tooth' contains a hundred times more truth than the command 'Whoever shall smite thee on thy right cheek, turn to him the left also'. Nevertheless, you must follow Christ, and live in the hope that the struggle for existence, the destruction of the weak and the rapid reproduction of the moral amongst men, will lead the world into the longed-for Paradise.

Some of the thinkers who, with Darwin and Spencer, were trying to form some picture of the evolution of the world, of religion, and of morality, turned to the study of the past. They endeavoured to build up, from a basis of moving atoms, the manifold variety of the present world. Zöllner, Fechner, Preyer, Haeckel, Von Hartmann, were among these. Others were more concerned with mankind, and painted the advance in morality which the future was to bring. Among these were Fiske, Barrat, Williams, Leslie Stephen, T. H. Huxley, Alexander, Wallace, Clifford, Romanes, Benjamin Kidd, among Englishmen; Rolph, Wundt, Barth, Carneri, Vetter, and Büchner, among the Germans; the Dane Höffding; the Russians Metschnikov and Novikov; the Frenchmen Fouillée, Guyau, Ribot, and others.

The views held by these philosophers concerning the nature of human progress were not identical, but the

majority accepted the idea of a struggle for existence, and they dealt chiefly with the transition from a nature 'red in tooth and claw' to one in which the higher moral laws —where 'Love thy neighbour as thyself' was the reigning command.

Huxley was the first to realize the impossibility of any such transition; he asserted that moral law is contrary to 'natural law'; that morality and duty are at war with the animal instincts, and that ethics cannot possibly be only 'applied natural history'! These criticisms were aimed directly at Spencer's views. Huxley thus discovered the fundamental error in the evolutionary theory. While asserting that the origin of ethical ideas is to be explained by the new teaching about nature, it simply retained the moral principles characteristic of Christianity. In this respect evolutionary ethics were like evolutionary biology, and aimed at explaining the evolution of known ideas rather than at introducing new ones.

VII

THE INFLUENCE OF THE DARWINIAN THEORY IN OTHER FIELDS OF INTELLECTUAL ACTIVITY

IN the early nineteenth century all German philosophy was—in spite of differences between the different systems—conservative in tendency. In certain details, it is true, a Goethe, Oken, Fichte, or Hegel might disagree with prevailing opinion, but, even when they seemed most iconoclastic, their whole thought was directed to the understanding of existence as it is. The culminating point of this philosophy was reached by Hegel, and expressed by him in the well-known sentence 'What is reasonable is real, and all that is real is reasonable'. This belief was fatal to all hopes of influencing the world's events; for, if all that exists is 'reasonable' (i.e. a manifestation of reason), any effort to enrich or to ennoble the world is meaningless! Hence Hegel became a pillar of conservatism, and his point of view was repudiated by the 'Young Germany'. As the movement to the Left began, and this ever-growing Radicalism brought with it a belief that all reasonableness and all truth must be relegated to a far-distant future, there arose a great discontent with this view of existence. 'Everything that is, is unreasonable' was the cry of the new agitators, and they held that it was the task of science to improve and to revivify the world. By exact science they meant Positivism in France, but in Germany Materialism and Darwinism. One result of this tendency was that the most varied sciences and other spheres of thought now began to replace their earlier rationalistic systems by some form of Darwinism.

Like an oncoming flood, the conviction spread that no science, except physics, chemistry, and the Darwinian conception of natural history, contained any absolute truth, but that all other branches of knowledge would have to be revised and remodelled, basing themselves on this, the

only exact knowledge we have. Kant's axiom, that in every science only *that* is exact which can be mathematically expressed was adopted with but slight change. Instead of mathematics were put physics, chemistry, and natural history. The ideas of struggle for existence, natural selection, heredity, atavism, degeneracy, were separated from biology, accepted as of real value, and introduced into the most varied fields of intellectual activity.

Darwin himself helped to bring this about when he endeavoured to account for such diverse phenomena as the origin of birds, of religions, of the instinct of bees, of flowers, and of colours, by his theory of natural selection. If such heterogeneous things could be explained by this theory, why should it not be able to account for the origin of chemical combinations, or of the European States? It is not possible to examine all the cases where there was an endeavour to transplant Darwinism into the most diverse fields of knowledge. We can only indicate some of the most important among them.

Chemistry, Petrography, Astronomy.

Many attempts were made to introduce the Darwinian theory into chemistry. J. C. F. Zöllner, the well-known physicist and spiritualist, declared that:

'Positive and negative electricities are the fundamental units of matter, and in course of time all chemical elements were formed from them. These changes were the result of mutual reactions, and new elements were formed in response to given mechanical conditions. New species of plants and animals arise in a similar way. They are the result of natural selection and arise as adaptations to complex conditions of existence' (*Über die Natur der Kometen*, Leipzig, 1873).

L. Pflaunder, Innsbruck, studying the origin of certain chemical compounds by dissociation, saw an analogy between these reciprocal reactions and natural selection (1867). C. Nägeli, the well-known Munich botanist, believed that all the elements in each of Mendeléeff's groups arose in the same epoch and in the same region of

the universe; that the heavier elements were formed before the lighter ones; that the group to which platinum, iridium, and osmium belong arose first, and that hydrogen was the last to be formed (1884). Other hypotheses concerning the origin of the elements and the struggle for existence of the molecules were published by W. Preyer, Viktor Meyer, W. Crookes, C. Wendt, and others.

Darwinism was also used to explain the origin of mountain ranges. J. Walther, the geologist, tried to prove that some minerals are less susceptible than others to the action of the environment. These have survived, and form the most ancient mountain groups of to-day; others were more easily destroyed by the action of rain, of acids, of mechanical forces, and hence took little part in such formations (1895).

V. Meunier (1871) and the Freiherr du Prel (1874) transferred the idea of the struggle for existence to the heavenly bodies; they supposed that it was raging at the time when the nucleus of the solar system was being formed by condensation from primeval substance; stars incapable of a separate existence collided and were destroyed, until finally only those moving in a suitable manner survived.

Origin of Colour Vision.

The subject of psychology will be dealt with in a separate chapter; here we shall only refer to the attempt to explain colour vision as the product of evolution.

H. Magnus developed the idea that men were originally colour blind, and that they first learned to distinguish red, then yellow, then light green, and finally blue and violet; he thought that a time may come when ultra-violet light will also be visible to the eye (1877). Before the time of Magnus, Gladstone and Geiger had asserted that the ancients (Homer, for example) could not distinguish blue from black, nor green from grey. They referred to the writers of the Bible, to Aristotle and other writers of antiquity, to obtain evidence which would support this

view, but the theory did not long survive, and it was criticized even by Darwinians as E. Krause.

The Science of Language.

The Darwinian theory became of greater importance in the science of language than in the above-mentioned branches of knowledge. The methods of comparative philology and comparative biology were already very similar. The morphologists compared the structure of different organisms, determined what they had in common, and so created 'types'; the investigator of language compared the words of various languages to discover common roots. Just when morphological speculation was most flourishing Fritz Bopp (1791–1867), the originator of the science of comparative philology, began his work; he based his science on the discovery of common roots (e.g. the words am, ásmi, εἰμί, sum, suis, im, jesmi). The differences of opinion which arose about the development of language resembled the biological discussions concerning preformation and epigenesis. Some, among them Bopp himself, asserted that the words of existing languages were evolved from definite roots, and that the changes were regulated by laws inherent in the roots themselves; others (including Schlegel) stoutly affirmed that words have arisen by a gradual blending of sounds (agglutinization)—i.e. by a sort of epigenesis. Under the influence of those investigators, and of Herder, Humboldt, and Hegel, the origin of language became a favourite philosophical theme. Thus when Darwin appeared with his views, many philosophers fitted their ideas into his theories.

The science of language was steered into the Darwinian current by Schleicher (1821–1868), Haeckel having first drawn his attention to *The Origin of Species*. He published a pamphlet in which he stated that the idea voiced by Darwin was by no means new to those engaged in the study of speech. They had long been studying the evolution of language. They could, however, now learn from the naturalists that only definite objective facts and con-

clusions derived from them are of any value in this field of research. 'For the study of language (philology) is really a sort of natural history.' (Schleicher, *Die Darwinsche Theorie und die Sprachwissenschaft*, Weimar, 1863.)

'I well know how much I owe to the study of such works as Schleiden's on botany, and Vogt's physiological letters; how much these works influenced my ideas on the nature and life of language. . . . From these books I first obtained my knowledge of evolution. The naturalists teach us how important it is to study facts based on unbiased observations, and the conclusions derived therefrom. Languages are natural growths. They have arisen independently of the will of man; they grow and develop according to definite laws and they finally decay and die out. Hence they exhibit the characteristic features of a living organism. . . . The science of language is therefore a natural science.'

For this reason, Darwin's theory and Haeckel's monism are relevant in the science of language too. We need only to alter the terminology a little.

We call the genera belonging to one species the languages of one group; sub-species are dialects, varieties are idioms. Biological units are individuals differing in slight degree; each man's speech is individual too, differing slightly from that of all other men. We can construct genealogical trees for languages, as we do for animals. Languages develop, as their common roots testify, from one original stock. In course of time, languages developed and their number increased, until the tongues of the present day were evolved. This differentiation was brought about by variation in the conditions of life, and modern languages, in spite of great differences, still carry with them the direct evidence of a common origin.

Schleicher's arguments were approved by the naturalists. Haeckel quoted them in his writings; Lyell also referred to them favourably in his *Geological Age of Man*, and Darwin gave them a friendly notice in his *Descent of Man*. Many philologists and philosophers agreed with this view, that speech had evolved in accordance with Darwin's principles.

There were also several widely accepted theories which dealt with the origin of the capacity for speech. Darwin himself discussed the question; he explained that speech began in the imitation of various sounds and of animal voices, and in the instinctive human cries. He pointed out that some monkeys (e.g. *Hylobates agilis*) can, in a certain sense 'sing', and he believed that man was once at the same stage of development, able to sing some musical cadence for the amusement of his mate, but otherwise without speech— *homo primigenius alalus*. Gradually, from such song, articulate sounds developed, then words by means of which man could express his many and varying emotions.

Jaeger attempted to show the definite steps by which speech may have evolved from animal sounds (1888). These animal sounds begin as chance ones—for example, the buzzing of a fly. They then become intentional—for example, the chirruping of a grasshopper. This sound produced at will—this interjection—is the first step in the development of language. A higher stage is represented by the call with which the male allures the female; a still higher by the imitative song characteristic of many birds. Social life produced new sounds among animals, and so there was further progress. Speech, then, was originally a series of sounds expressing subjective conditions. It is still at this stage of development among the grasshoppers, the cicades, &c. It became a call; then it passed beyond the merely subjective, and became an appeal to companions. Jaeger thinks the power some animals possess of pointing out noteworthy objects (a goose points towards a hawk) may be related to this power to call.

It was assumed that a still higher stage of development is represented by the 'pictorial word' used by primitive man when he begins to express his sensations by sounds, instead of by gestures only. So arose the roots of our words —'ac', for example, was supposed originally to have expressed pain. In another place Jaeger explained why animals so seldom produce varying tones and sounds. The

lung in the act of expiration provides the necessary preliminary for the formation of sounds with definite nuances, whether spoken or sung; but the accompanying movements of the chest cavity are impossible to four-legged animals—chest movements in these animals being affected by every motion of the fore-leg.

Similar theories were upheld by other philosophers in the eighties of last century. The views of Schleicher, the fantasies of Bopp and Jaeger, have long been abandoned. Philologists have given up the idea that the roots which they abstracted from various languages once existed as independent words. Schleicher's genealogical tree has only an historic interest, and no one now supports the view that languages were developed from inarticulate interjections. The fundamental hypothesis itself—that the study of language is applied natural history—was supplanted in the eighties. The reaction came from workers who believed that speech must be a product of the human intellect and that the methods of the naturalists, deduced from a study of the body, are therefore not applicable to it.

Pedagogy.

The new philosophy exerted a twofold influence upon educational ideas. Firstly, the evolutionists claimed that scientific methods and the results of scientific discovery must be taught in the schools; secondly, that all our views about life must be revolutionized.

Spencer, Huxley, von Baer, and a host of other investigators urged that the schools should 'move with the times'. They would have abandoned the classical education in favour of the study of chemistry, physics, and natural history. In every country—but most of all, perhaps, in France—educational practice more or less adapted itself to the new theories. This movement is, however, probably now on the wane, although it still has many defenders.

The idea that the man is a part of society and of the race, and that the health of the race depends upon the health of each of its units, also affected pedagogy. The

children must be kept healthy if the future generations are to be strong.

Evolutionary philosophy in the form of Haeckel's fundamental biogenetic law brought about further changes in educational theory. Spencer, Preyer, and others thought that man recapitulates the stages through which his forefathers have passed, not only during his embryonic life, not only during his childhood, but through all the stages of his intellectual development. Some saw in this a reason for teaching the classics. Since antiquity represents a stage in the development of the human spirit, the study of the classics must be a necessary part of the education of the young.[1] The physiologist Preyer deduced his child psychology from Haeckel's law; the study of the mental processes of the child will enable us to picture the former mentality of man. This new science was accepted by Darwin himself, by Romanes, and particularly by the American psychologist Baldwin. Pedagogic ideas were further influenced by the new views concerning heredity and natural selection. 'Given the inherited advantages and disadvantages of a race, in how far can this inheritance be altered by education?' This, affirmed Guyau, was the problem which the educationalists must attack, and he claimed that educational practice should be based on the physiological and ethical laws of racial culture.

Fouillée agreed with him and repeated, 'The object of education is to produce new inheritable qualities, which shall be advantageous to the race, both physically and psychically'. He called in Natural Selection, though in a modified meaning of the term, to help in the process. He thought of it not as selection in the struggle for existence only but as selection during a struggle for the improvement of life in its physical, intellectual, and moral aspects. Genetic ideas also invaded pedagogic practice. Since everything has been evolved, Spencer's idea was adopted

[1] Herbart, and his pupil Ziller, had already affirmed that every single man, in the course of his intellectual development, repeats the various stages of cultural development through which the whole human race has passed.

that pupils would best understand their teacher if he explained the object of study genetically. Thus, for instance, in the study of natural history, the older method—that of beginning with man and ending with microscopic organisms—was declared to be unsound. Then it was thought that the teacher should advance from the known to the unknown, but now it was held that instruction should begin with the amoeba, with the single cell from which all life has evolved. A lecture on the brain, for example, should begin with the amoeba, pass to a ganglian cell, then to the brains of fish, frog, rabbit, and ape, to end finally with the human brain.

It was under the stimulus of Darwin's theory that John Dewey, an American philosopher, formulated his pedagogic system. The influence of this system spread through the whole civilized world, but it would be beyond the range of this book to discuss this subject more fully.

History and Sociology.

Darwinism exerted a profound influence on all our ideas about the nature of human society and human history. At the beginning of the nineteenth century the German philosopher Hegel, following the example of his fellow countryman Herder, had conceived of a universe in evolution: starting as a subconscious God, and evolving into matter in motion, into the world of plants and animals, into human society, into art, science and the state, into religion. This philosophy exerted a profound influence, especially upon historians and sociologists.

When, in addition to this, Comte and Buckle propounded the ideal of 'scientific' history—by the study of which it should be possible for the historian to enunciate definite laws which underlie human affairs—the foundations were laid for a Darwinian interpretation of history and of sociology. Buckle, in a book that appeared at the same time as Darwin's *Origin of Species*, suggested that writers of history should first collect and analyse their facts, then deduce from these facts general formulae, and that their

final endeavour should be to formulate universal laws, after the manner of a Kepler or a Newton.

Since there is always a mutual interaction between man and nature, the conditions of both must be studied. The historian must not neglect to ascertain the influence of food, of climate, of the soil, of the general environment. Buckle, analysing the history of English civilization according to these principles, came to the conclusion that it consisted simply in a continual conquest of nature by man, and in the ever-increasing intellectual training resulting from this endeavour to overcome natural difficulties.

The influence of natural science on historical thought and historical writing was very much heightened by Buckle's book. Comte's attempt to draft a hierarchy of the sciences exerted an equally strong influence. He placed sociology above biology, and recommended that biological methods should be introduced into sociology. Taine, following in his footsteps, made it his task to win acceptance for biological concepts in the study of history.

These investigators only linked up history and biology in the most general way. But there were a whole series of workers who tried to introduce Darwinism into the details of historical work. Of these Herbert Spencer was leader; he pictured society as an organism, and as, according to the materialistic theory, the living organism is merely an aggregate of cells, so is society according to Spencer an aggregate of men or of families. Further, society, like the organism, has a definite structure. Among civilized peoples the ectoderm is composed of the warriors, the endoderm of the women and slaves who attend to the household. As the nervous system is developed from ectoderm, so from the warrior caste are derived the rulers of society. Just as mesoderm develops later between these embryonic layers, so in human society there arises between the warrior and the producing classes the class devoted to trade. A peace-loving government is to be compared with the sympathetic nervous system; a war-like one, on the other hand, with brain and spinal cord. The struggle for existence and its

consequent natural selection occur both in nature and in society; the progress of a society consists in a continual better-fitting of its individuals to the conditions prevailing in that society.

As interpreted by Spencer, sociology became strongly affected by Darwinism. Karl Marx and Engels, in particular, sought to introduce Darwinian theories into their extremely materialistic sociological philosophy.

Social Democracy.

The social democrats looked with favour upon the Darwinian theory, since in its materialistic and anticlerical tendencies it coincided with their ideas concerning the universe. Both Karl Marx and Engels, who had attempted to give a new and materialistic interpretation of Hegel's philosophical history, showed great reverence for science. In this they were like most of the philosophers of their time; these accepted Darwin's teaching as unquestioningly as if it consisted of actual, well-established scientific facts. Later on Socialists both read and wrote many popular books on the subject of evolution.

When Virchow pointed out the connexion between social democracy and the teaching of the evolutionists, some Darwinians made a great effort to emphasize the points in which the two theories seemed to be logically opposed. Oscar Schmidt, a follower of Haeckel (1878), declared that Socialism and Communism, movements which strive for the equality of man, only occur in Nature among social animals in the lowest stages of development. The more advanced life becomes, the more is this undifferentiated equality destroyed, and the more is the egoism of the individual enabled to gain the upper hand. The view of evolution expressed by Marx and Engels, continued Schmidt, is quite different from that held by Darwin. They believe, as did Hegel, in something abstract, in an idea of evolution. Darwin is only concerned with actual events, with their causes and their results. Further, this Socialistic ideal of equality contradicts the facts of natural

selection; for natural selection demands an inequality between organisms as the essential factor underlying every advance.

Schmidt's explanation was doubtless the correct one, and Darwin, Huxley, Haeckel, and others were voicing their innermost convictions when they asserted that their views were contrary to those of the Socialists. Nevertheless, we can hardly regard the friendly reception given by the Socialists to Darwinism as a mere chance. At the present time the view usually held is that the evolutionary theory is an aristocratic one; the stronger wins in the struggle for existence, and to secure his survival hecatombs of his weaker brethren are sacrificed. There is much, however, to be said against this view.

Firstly, the words 'aristocrat' and 'democrat' are being used here to denote a logical idea rather than anything in actual existence.

Secondly, the idea of a selection of the best types forms, it is true, the nucleus of the Darwinian theory; but we cannot regard this idea as a purely aristocratic one, for it does not contain that fundamental characteristic of aristocratic thought—the picture of an individual who gains his ascendancy *by his own powers*. The struggle for existence is merely Darwin's name for a blind mechanical process.

Thirdly, the theory contains one completely non-aristocratic conception, that of the influence of the environment upon the organism.

Fourthly, we note that the general ideas of Darwin, of Spencer, and of Haeckel, the founders of Darwinism, were much more nearly democratic than aristocratic. Remember Darwin's intense objection to giving pain to animals; his mechanistic philosophy; his comparison of men and monkeys; his most honourable condemnation of slavery; his hope for the progress of mankind!

It is easy to understand why the leading Darwinists did not want to admit a connexion between their views and those of the Socialists. They looked upon the Socialists as a party dangerous to the State, and in this respect they

were completely opposed to socialistic teaching. The Socialists, however, sensed the democratic background of the new philosophy; they agreed with the Darwinists in their struggle with the Church and in their idealistic philosophy; they agreed also in their materialistic ideas concerning mankind. The fact that their leaders had begun as Hegelian idealists affected them little—had not the materialists Strauss and Feuerbach been his pupils?

In our times conditions have completely altered. Nietsche introduced a strongly individualistic tendency into Darwinism, while, on the other hand, the theorists among the social democrats have no longer any very profound belief in either Darwinism or Materialism, nor indeed any special love for science. Modern Darwinism—or at least that form of it preached by the eugenists—may be regarded as an aristocratic theory.

Literature.

During the seventies in Germany there appeared a large number of poems, novels, and romances dealing with Darwinian themes; the struggle for existence, the glorious future of mankind, the life of antediluvian man, and so on. The French naturalistic novel was written under a very strong Darwinian influence. As Darwin excluded idealism from biology, so did Zola wish to banish from the novel all domination of personality by the will, by reason, or by the ideal; he tried to eliminate the soul, and to replace all these higher faculties by the action of instinct and of heredity. Haeckel's genealogical tree also reappeared in light literature, when Zola ended his cycle of Rougon-Macquart novels with a table showing the descent of his heroes. Neurasthenia, drink, and sexual excesses (Dr. Pascal) had burdened them with such an unfortunate heredity that this could only lead to the downfall of the whole family.

Zola's ideal novelist was like Darwin's ideal naturalist. Darwin did not strive to understand Nature, as this might introduce a subjective element into science. Every theory

must be quite impersonal—it should merely supply us with a picture of what is actually happening in nature. In a similar manner Zola banished fantasy, and asked for nothing from the artist except facts arranged in the proper order. The hand of the writer was not to be noticed in his works; he must not order the facts according to his will; he is merely a recorder, and must give them free play. Interest in Zolaesque naturalism quickly faded, but interest in the doctrine of evolution survived.

Brunetière led a bitter campaign in France against naturalism, leaning so far towards the Right that he almost landed in the Papal camp. Nevertheless he was a firm believer in evolution, and began his critical essays by assuming that literary tendencies are species, analogous to biological ones, which arise, develop the organs they require, reach their height, then fall or become modified into new ones!

Darwinism exerted a great influence on the literature of other nations. This influence would obviously be modified in each land by the national character and the prevailing conditions. In England it manifested itself in a philosophy of very concrete ideas; in Germany it became a creed, a scientific system; in France it appealed to the 'literati'; in America Darwin's friend Asa Gray upheld his views, but the teaching does not appear to have produced any very characteristic effects there; in Italy the theory was taken up both by scientists and by popular writers. The Italians even cited some of their own fellow countrymen as 'forerunners' of Darwin.

In Russia Darwinism became a part of that stream of positivism and materialism which began to flood the country in the middle of the nineteenth century. Before that time intellectual Russia was under Hegel's influence. A strong reaction against idealism now set in, and natural science was called in to help in its overthrow. The words of Pisarev[1]—one of the most important interpreters of

[1] Quoted from Ovsjanniko-Kulikovskij's *Istoria russkoj intelligencii*, Moscow, 1907, vol. ii, p. 374.

this movement—may be cited as characteristic of the time:

> 'To drive the common folk (profanum vulgus) out of the temple of Science does not suit the spirit of these times. An aristocracy of art is a most reprehensible phenomenon. A monopoly in science and education is the most dangerous of all monopolies. What sort of a doctrine is that, the very essentials of which are unintelligible to the masses?'

Pisarev held that such abstract subjects as philosophy and psychology merely represent an empty scholasticism, and that natural science must be presented so simply that ten-year-old children and uneducated peasants can understand it.[1]

Such views gained a great deal of sympathy in Russia, and were supported by the translation of such materialistic writings as those of Vogt, Lange, and Büchner. Büchner's *Kraft und Stoff* was long banned in Russia. The works of Darwin, Spencer, Haeckel, Wallace, and Romanes were translated, and helped to forward the movement; the translations of Haeckel's work were confiscated.[2] The desire in Russia was more for exact knowledge than merely for materialist doctrines. Liebig was praised as well as Vogt, von Baer as well as Haeckel. Some of the personalities of this time won fame even beyond the Russian border—the two Kovaleskys (the palaeontologist and the embryologist), Cienkovsky, and Metchnikov among others.

Criminology.

Most schools of jurisprudence consider each man responsible for his own acts. In the seventies Cesare Lombroso, a professor at Turin, brought forward evidence that there are criminals in whom lawlessness is inborn; that such men are a class apart, showing many of the physical and psychical characteristics of uncivilized man and of animal ancestors. These characters are therefore atavistic. The view of Paracelsus that the fool is a 'man

[1] *Ovsjanniko-Kulikovskij*, p. 375.
[2] Professor Vernadskij gave me this information.

who went wrong in the making', was expressed in a modern guise. Ferri, Lombroso's follower, distinguished between the criminal lunatic, the born criminal, the man who has acquired criminal habits, and the man who commits a crime of passion. Lombroso adopted this classification and asserted that the born criminal shows definite physical signs of degeneracy, among which are: pathological skull-formations; varying number of such organs as nipples, fingers, and teeth; irregularities in the convolutions of the brain. Ape-like characters found among criminals are, in particular, a very small brain; thick, heavy eyebrows; the continuation forwards of the *processus jugalis;* large eyesockets; protruding teeth; very heavy jaws; a peculiar shape of the ear-muscles.

In these, and in many other characters, the criminal is supposed to resemble the monkey in structure. He is less sensitive to pain than normal, and likes to be tattooed; he is often left-handed; when his arms are horizontally extended, the length from finger-tip to finger-tip is greater than his height; his body is hairy; his sex less well-defined; his heart less easily stimulated; wounds less painful. Mentally he is on the plane of uncivilized man. Hence we get criminal prostitution, cannibalism, cruelty, the blood feud, the dislike of honest work, the typical carelessness, moodiness, and conceit of the criminal. Lombroso affirmed that forty per cent. of all the inmates of prisons belong to this criminal type.

Many lawyers and doctors accepted Lombroso's views. Serious investigators do not now attach great importance to Lombroso's anatomical description of the criminal type, but many experienced lawyers and psychiatrists hold that some men are born with criminal tendencies.

VIII

DARWINISM AND RELIGION

THE Catholic Church not only teaches definite religious doctrines, it also gives a definite teaching concerning Nature. This consists of a mixture of ideas, taken partly from ancient Jewish natural history, and partly from the views of the Holy Fathers of the Church, interpreters of Galen and Aristotle. These ideas were once living. The words of Genesis, in which a Moses gave for the first time to his contemporaries his view of the world, were in his day truths as definite and as incontrovertible as any of our truths of to-day! At the time of their first enunciation, the teaching of St. Augustine, the truths of the Scholastics, represented convictions as firm and sure as our modern teaching of the origin of men from animals. It was not this truth, however, this deep personal conviction of Her founders, that was upheld by the Church; that living Truth, which cannot be expressed on paper, which only exists in man's deepest soul. The Church defended the mere words—the words by which those thinkers, long dead, had sought to express their relation to the Universe. 'When we speak, we begin at once to err,' says the poet. But the Church made these fossilized words the very foundation of Her teaching.

Modern natural history has in part developed out of this Biblical natural history. The older 'biologies' were enumerations of the animals of Noah's Ark, or taken from St. John's Book of Revelation. Thus science began, and ever since it has been her constant endeavour to escape from these origins. To the men of the Renaissance, entering into a healthier relationship with nature, the fantastic animals and unnatural ideas of more remote times became mere empty words. Belief in Biblical natural history had long been abandoned, although the

Church had not freed itself from this antediluvian story —indeed has not done so to this day.[1] She cannot free herself, for the Bible makes no distinction between theology and the philosophy of Nature; both are depicted as equally true. Even if the Church did admit the falsity of some of its concrete teaching, what can the present-day naturalist say to angels, to saints, to the whole content of ecclesiastical dogma? Nowhere, either in his facts, in his theories, or in his philosophy, does he find any point of contact with these dogmas.

The theologians themselves recognize this fact, but they do not admit that this is a failing of modern theology. They point out that this or that man has been able to reconcile theological teaching with exact science. This is certainly true. It is doubtless often true that 'thoughts can live peaceably next each other'. But they should not live 'next each other'. They should permeate each other, making a logical whole. His theology should be obvious in the theories and discoveries of the orthodox investigator. The saintly Kepler believed that the planets are moved by angels. When Kirchner first had the idea that water may occur on other planets, he at once asked himself whether Baptism with water from Venus would be valid. Napier, the discoverer of logarithms, discussed with equal earnestness those complicated properties of numbers, and the question whether migratory locusts may have been Mohammedans by religion. That was a science saturated with theology; a science of honest conviction, a theology of honest conviction, pursued by investigators with honest convictions! Present-day theologians should demand an equal single-mindedness from their modern adherents. It is another question whether such a union of science and theology is possible to-day.

It was neither Darwin nor Lamarck who began the

[1] 'Qui in locis authenticis Librorum sacrorum quidpiam falsi contineri posse existimant, ii profecto aut catholicam divinae inspirationis notionem pervertunt, aut Deum ipsum faciunt erroris auctorem.' 'Enzyklika Providentissimus Deus' of Pope Leo XIII, 1893.

controversy between modern biological theorists and the Church. In De Maillet we find a carefully worded anti-clerical polemic, and a fuller one in Robinet. The latter devotes the whole of the second volume of his *Natural Philosophy* to an investigation of the cosmogonies of different nations, and to the proof that the story given by Moses cannot be accepted as literal truth. He concludes from the Greek text of the Bible (*ἐξ οὐχ ὄντων ἐποίησεν αὐτὰ ὁ θεός*) that we need not assume that God created the world out of nothing. He prefers the hypothesis that there is a periodic growth and decay of the world, and he quotes sentences from St. Augustine and St. Origen which seem to him to support this view.

Cuvier showed that the extinct animals are distributed in periods of time, and on this he based his catastrophic theory. This theory cannot be reconciled with the first and second chapters of Genesis; these chapters tell us that the earth '*was* without form and void', not that it *became so*. That was, however, the least of the difficulties. In the Biblical story only one Act of Creation is described. There is no reference to any water, to any rocks, continents, or plants which preceded the present ones. Nevertheless, the Church did not oppose Cuvier, for he did not stress those conflicting points which were the logical deductions from his theory.

The Views of Darwin and the Darwinists.

In matters of religion Darwin was a true son of his times—a free-thinker. He did not deny the existence of a God, but for him it was an empty word, for it represents neither the Creator nor the lord of Creation, neither the inspirer of morality nor keeper of the soul. He plays no part in the world's story, neither in its past nor in its future. One thing only did He do for this world—He created the first forms of life, and then, having created them, left them free to 'evolve' as they would.

Darwin did not believe man to occupy any special place

in the Universe, nor did he believe the Universe to be controlled in any way by God. By mere suggestions at first, but later as a definite theory, he affirmed that Man is no more than a more highly developed monkey. He examined dogs in an endeavour to find the beginnings of religious sensibility; he thought that it was quite useless to begin a scientific inquiry into the nature of religion, for religion is unscientific. Although religious thought has played so great a part in human life, he did not think it necessary to study the facts of religion, nor to consider the views of the great religious teachers. He thought, as does the man in the street, that he was well qualified to discuss the nature of religious conviction after having read two or three books on the subject.

His ignorance angered the specialists. Max Müller, for example, speaks of him with something like contempt. Rationalists of the old school, like von Baer and the Duke of Argyll, were offended by the general attitude of Darwin and even more of Haeckel, to feelings which they themselves, in spite of all their 'liberalism', held most sacred. In their struggle with the Church, the German materialists, on the other hand, gave a very hearty welcome to Darwinism. 'Science is the most effective weapon which we can use against either Jesuits (whether Catholic or Lutheran) or the Ultramontanes,' wrote G. Seidlitz (1875), and by 'science' in this connexion he really meant Darwinism.

Strauss was most enthusiastic about the new ideas, and in *Der Alte und der neue Glaube*, he gave a full explanation of Darwin's views, and added:

'The theory is still incomplete; but there is something in these ideas which has an irresistible attraction for all those whose spirits thirst for truth and freedom. It was all very well for us philosophers and critically-minded theologians to banish the supernatural. Our decrees were uttered in vain; we did not know how to dispense with it; we did not know any natural processes which would replace it in those realms which seemed peculiarly its own. Darwin revealed those natural forces, those natural processes. He opened a

door through which we might now thrust the supernatural into eternal banishment. All who know what belief in the supernatural has meant will acclaim him as among the great liberators of the human spirit.'

These words show us what the materialists were promising themselves from the new faith. The anticlerical, almost antireligious, tendency of the whole theory was one of its chief recommendations, and the Darwinists were very sensitive about the 'Credo' of their co-workers. Those who were anti-Darwinian were decried as Papists and reactionaries.

Von Baer, Wigand, Owen, and Cuvier were dismissed as old fashioned; the Church took them all under her broad wing, never asking whether they really belonged there, and She defended them all, though unskilfully, against the intolerance of the Darwinists.

The Attitude of the Church.

The theologians were not united in their attitude towards Darwinism. The story of Galileo gave them caution, but it was impossible to accept the materialism of the new theory. Soon after the publication of the *Origin of Species*, Bishop Wilberforce wrote a criticism of the book (1860). Darwin was, according to him, a superficial thinker who had 'wandered from the broad highway . . . into a jungle of fanciful assumptions' and 'flimsy speculations' (*Quarterly Review*, 1860). He suggested that it is not very likely that Man has been evolved from a potato, and he allowed many similar foolish witticisms to appear under his name.

All theologians did not adopt this attitude, however. Darwin, in the *Origin of Species*, refers to 'a celebrated author and divine' who wrote to him that 'he has gradually learnt to see that it is just as noble a conception of the Deity to believe that He created a few original forms capable of self-development into other and needful forms, as to believe that He required a fresh act of creation to supply the voids caused by the action of His laws'. In later times, theologians wavered between these two views.

Huxley met with great opposition from orthodox ecclesiastical circles when he publicly proclaimed his belief that Man is descended from an ape-like ancestor. At the meeting of the British Association held in Oxford in 1860 there was a pitched battle between Bishop Wilberforce and Huxley. In 1864 a definite opposition to the new ideas was organized. Two hundred and ten scientists, among whom were Day, Brewster, and Balfour, declared that 'there cannot be any contradiction between the divine revelation given to us in the book of Nature and that revelation which is contained in the Bible. It is much to be regretted that certain scientists have attempted to use their science to question the accuracy of God's Holy Book.' Many scientists, however, whose religious views were quite orthodox, refused to sign this declaration.

Among German protestants the new theory soon gained many adherents, who accepted it either in part or as a whole. Zöckler has given an account of this movement, and he himself criticized the theory very freely. More recently, the idea of evolution has not been absolutely rejected even by Roman Catholic theologians.[1]

The theologians found themselves in a difficult position. They knew something about modern science, and did not want to appear quite unscientific. In all haste they adopted a few scientific ideas, and are full of wise saws and modern scientific instances. They cited Cuvier to refute Darwin, Darwin to contradict Huxley, Huxley to silence Haeckel. Listening attentively to their discussions, we are sometimes tempted to believe that they had a higher regard for these scientists than have the biologists themselves.[2]

There were a few scientists who attempted to reconcile the theory of evolution and the belief in the literal accuracy of the Bible. Soon after its publication, St. George

[1] The names of some of these are given by Duilhé St. Projet in *Apologie de la foi chrétienne*, 1885. Wasmann also gives the names of certain of them.

[2] In the *Kircherlexikon* (1886) an account of Darwinism is given, culled from scientific sources only; the criticism is also a scientific one, taken from Wigand's works.

Mivart criticized the *Origin of Species* from this point of view. He discovered gaps in the theory of natural selection, and brought these to the notice of Darwin. He himself did not wholly reject the idea of evolution; he did not even object to the view which derived Man from an ape-like progenitor; but he felt convinced that God must have directly intervened when Man was first created. Lyell and Wallace both favoured this idea, and Mivart gained a considerable reputation.

Somewhat later (1904) Erich Wasmann, a Jesuit, created a certain sensation by his discussion of these problems.[1] He attempted to effect a reconciliation between the Church and Darwin and between Darwin and the Church. He is really attacking both points of view. He not only accepts and defends the general doctrine of evolution, but he even admits that it is probably applicable to Man. We must, however, believe, according to him, that God actively intervened twice in the whole story; once when life began, and once again when the human soul was created. Apart from these two interventions, the whole process goes forward without any direct control by the Deity. God was, however, essential for these two events, for living material is absolutely different from lifeless matter. God added something to lifeless matter before life could arise. The human soul is a further addition, which could only have been breathed into the animal body by God Himself.

Wasmann's criticism of Darwinism is not very enlightening. He calls it, for example, 'mere tomfoolery done in the name of science', 'philosophical ineptitude', 'theologically nonsense', 'social nonsense'. 'Haeckelism,' he says, 'aided by Darwinism, has become a pillar of Anarchism and of Social Democracy, as Bebel recently pointed out in the Reichstag.'

He showed that the general belief in Church circles had been that there exist just as many species as were

[1] E. Wasmann, *Die moderne Biologie und die Entwicklungstheorie*, Freiburg im Br., 1904.

originally created. (Linnaeus held this view.) To reconcile this view with the ideas of Darwin, Wasmann postulated a difference between 'natural' and 'systematic' species.

The species, for the purposes of the systematist, is just what we usually understand by a species—*Equus caballus*, a horse. A 'natural' species, however, includes all forms which are related by descent. Thus the horse, the donkey, the zebra, and the hipparion all really descended from the one ancestral 'horse', form a 'natural' species.

Wasmann also accepted the idea of natural selection, and suggested that it might be made more comprehensive by being combined with an idea of friendly selection ('Amikal Selektion'). He quotes the ants and other insects as examples of this. The ants, as is well known, bring up the young of another species in their nests. They prefer insects which give off large amounts of fat, and they nurse the larvae of these 'ant friends' as they would nurse their own brood.

Wasmann's personality is so stimulating that his books are still read. Thus an 'open debate' between him and Plate aroused a great deal of interest. Plate is a typical Darwinist of the old school and judges religion purely from the scientific point of view.

Apart from these occasional outbursts, the controversy between the Church and exact science seems to be ended. We all realize now that the Bible does not give us any accurate scientific details, and so, to defend it, we have merely to admit this fact. The attitude of the modern churchman, as of the evolutionist, to this strife is perhaps best expressed in the words of Vogelsang, a witty geologist, who remarked:

> 'If Moses had only kept his geological theories to himself, Christendom would have lost nothing, but science would have gained immeasurably, for its development would have been more rapid.'[1]

[1] H. Vogelsang, *Philosophie der Geologie*, 1867.

But times have altered. We have abandoned all belief in the literal interpretation of the Bible, and no longer ask whether it was possible to crowd so many animals into Noah's Ark. Modern scientific criticism of the Bible is no longer based on physical science, but has taken an historical and philosophical turn.

Even this type of criticism is now giving place to a renewed interest in religion. If we regard the theology of Karl Barth as symptomatic of the new attitude to Darwinism and to Biblical criticism, what a change is here epitomized!

IX

BEAUTY IN THE WORLD OF LIVING ORGANISMS.

Darwin's Views.

WE all realize that plants and animals are beautiful. Butterflies, humming-birds, orchids, roses, seem like beauty personified. This may reveal itself as beauty of form—as we see in the markings of a butterfly's wing or in the human body, or in colour and texture, as in the rose, or in the velvety blackness of the mole; in scent; in motion, as we see it in the galloping horse, the bounding stag, or the wonderful curves described by the water-wagtail. There are beautiful sounds too, from the chirping of the grasshopper to the song of the nightingale. There are still other forms of beauty which we may specify—the beauty, for example, revealed by animals at play and in the forms of animals, and, finally, there is spiritual beauty.

The evolutionary philosophers believed that beauty, like everything in the universe, is merely the result of other qualities. They did not seek out or describe natural beauty, but assumed that it was generally recognized. They considered that it was their task to see how it might be accounted for historically—i. e. from the past history of the organism.

Herbert Spencer, for example, was looking at a table laden with good food, the dishes all elaborately garnished with green-stuff; in the middle were bowls full of fruit, and a vase of flowers. What thoughts did this sight arouse in his mind? We might suppose that his first idea would be a realization of the beauty of the objects spread out before him! But no—he thought of something very different; of primitive man still a tree dweller, living on the fruits of the untilled earth; and to him the well-laid table was 'explained' merely as a relic, a legacy, of those far-off times! Grant Allen, an evolutionary philosopher, not only found nothing bizarre in this idea, but he elaborated it still further.

Darwin himself attributed almost all beauty to utilitarian motives:

> 'With respect to the belief that organic beings have been created beautiful for the delight of Man, I may first remark that the sense of beauty obviously depends on the nature of the mind, irrespective of any real quality in the admired object; and that the idea of what is beautiful is not innate or unalterable. . . . Flowers rank among the most beautiful productions of nature; but they have been rendered conspicuous in contrast with the green leaves, and in consequence at the same time beautiful, so that they may be easily observed by insects. I have come to this conclusion from finding it an invariable rule that, when a flower is fertilized by the wind, it never has a gaily-coloured corolla' (*Origin of Species*).

Nature does not create beauty directly according to Darwin. What we call beauty is the result of the action of the environment, or of 'spontaneous variations and the complex laws of growth'; and we may conclude that otherwise 'the structure of every living creature either now is, or was formerly, of some direct or indirect use to its possessor'. Darwin admits that the secondary sexual characters form an exception to this rule. He believes, too, that animals possess a sense of beauty, but he cannot explain how they have acquired it. 'Habit in all these cases appears to have come to a certain extent into play; but there must be some fundamental cause in the constitution of the nervous system in each species' (*Origin of Species*).

It follows from this theory that we cannot hope that a study of Nature will reveal to us any fundamental aesthetical laws. We must abandon the idea that by studying the structure, markings, colour, movements, or any other features of plant or animal organization, we can ever learn anything about the ultimate value of beauty. We know all there is to know about beauty in Nature—and all that we can do is to ask how that beauty was acquired.

True to his usual method, Darwin looked to many quarters for the 'cause' of beauty. The celestial blue, the colours of the rainbow, the glories of autumn colouring in trees, the colour and brilliance of precious stones, the

colours of the lowest animals—all these are the results of natural laws. The Infusorian *Opalina* shimmers with all the colours of the rainbow, because light is refracted by its vibrating cilia. Many and various are the causes of the wealth of colour exhibited by so many of the simpler forms of life—by corals, medusae, starfish, echinoderms, and the like; here the colours are useful to the organism in some way, there they are the direct effect of its physical and chemical structure, and hence neither useful nor the reverse. The blood is not red because the red colour is useful; nor is it red in order that it may beautify the maiden's blushing cheek. The colour is simply the result of its chemical composition.

The beauty of flowers arose in yet another way. Many of these use insects for pollination. Since brightly coloured flowers are more easily noticed by insects, they are more often visited by them and are more likely to be pollinated. We owe most types of beauty, however, to the action of sexual selection. Even in quite lowly forms of life it is assumed that the female chooses for her mate the male who is most to her taste. The offspring of this union will inherit the advantages of their father—and thus, step by step, beauty increases. So have arisen the bright colours of the butterflies, the glories of the peacock, the song of the nightingale, the beauty of mankind! For this reason males tend to be more attractive than females; they pass on all their characteristics, more particularly to their own sex. In his *Descent of Man* Darwin gives many facts in support of this theory. He cites many cases where the male differs from the female in form, colour, or marking; and he explains all these cases in the usual way. The peacock's feathers, the horny covering of the beetle, the colour of skin, of hair and of beard in Man—for all these, as for all animal beauty whatsoever, Darwin gave what is really a psychological explanation. The taste of the female is the exciting cause of masculine beauty—the *cause* of it, not the *reason* for its existence. If this were not so, we could deduce the taste of the female from a study of the

beauty of her male partner. Any such experiment, any attempt to formulate general laws of beauty, would be quite un-Darwinian. Darwin firmly upheld the maxim *de gustibus non est disputandum.*

Grant Allen's theory of sexual selection was rather different. In his *Colour Sense*, a book on comparative aesthetics, he drew attention to the fact that the animals which haunt beautiful flowers and fruits are always themselves beautifully coloured, while those which live on a diet of flesh, like all those which live in the soil, are dingy in colour. The American humming-birds and the South African Nectariniidae are among the loveliest of birds, and both these groups live on flowers. This is true, too, of the flower-haunting beetles and butterflies. Birds of prey, dung beetles, and nocturnal animals are, on the other hand, usually inconspicuous. Allen felt that these facts proved that the taste of the animal is moulded by its surroundings, and that the male (or female) chooses its mate according to the taste thus formed. Many molluscs and snails have shells beautifully formed, marked, and coloured. Grant Allen could only suggest that all such features must be the result of 'mere chance'.

Darwin found in Hermann Müller (a secondary school teacher working in Lippstadt) a most industrious disciple, who whole-heartedly adopted his theory of floral structure. By this theory he sought to explain the harmony that so often exists between the shape of the flower and the size and mode of life of the pollinating insect (Darwin, Charles, *On the Various Contrivances by which Orchids are fertilized by Insects*, 1862). Müller collected many observations relating to this phenomenon. Many floral structures apparently exist for the sole purpose of attracting insects. The insects use their eyes and their organs of scent to find the blossoms, while the flowers, on their part, display various attractive mechanisms—the bright colours so often exhibited by calyx, corolla, stamens, floral axis, and bracts; the massing of many inconspicuous flowers into an inflorescence which stands out well from its surround-

ings; the enlargement of the marginal florets in the Compositeae—all these serve as attractive devices to catch the eye of the insect, as the sweet scent of the flower affects his sense of smell. This theory of mutual adaptation will explain many striking features of floral structure and especially those structures which force the visiting insect to enter the flower in some special way, and thus make the transmission of pollen more certain, as in the Salvias, the Orchids, in Aristolochia, &c., &c.

Müller divided flowers, according to their adaptation to certain insects, into butterfly flowers, moth flowers, wasp flowers, bee flowers, fly flowers, &c. *Dianthus*, for example, is only visited by butterflies; *Epipactis latifolia* only by wasps; *Silene nutans*, which is only scented at night, by night-flying moths.

Other Views of Beauty in Nature.

Many scientists, like Darwin and Müller, thought that floral beauty existed for such uses only. The theory had, however, its critics.

Claud Bernard had asserted that we must look to the organism itself, and not to any force outside it, if we wish to discover the final cause of any physiological process; for every living organism is an end unto itself, and is subject to the inner laws of its own being. Gaston Bonnier (1889) attacked the theory from this point of view. He claimed that the size and colour of flowers bears no definite relationship to the number of insect visitors. Mignonette, for example, has many visitors, while large lilies have very few. There are many lovely and sweet-scented flowers which have nothing to offer a visiting insect. Bonnier, like Müller, gave many facts which seemed to support his views, but this attempt to refute Darwin's theory made no impression.

Darwin's ideas about beauty were not always accepted even by those who believed in evolution. The weak points in his theory were, perhaps, nowhere so obvious as in his

attitude toward sexual selection. He needed instances to show that males who are not beautiful are rejected by the females they desire, and that the progeny of weakly and less attractive males *does* increase less quickly. But he did not attempt to find these. He did not even prove that there is a definite choice by the female, still less that such a choice, if it exists, exerts any influence upon the number or nature of the offspring. For this reason Wallace rejected the theory of sexual selection altogether. He believed that the more intense colouring of the male is due to his greater energy. It is, he held, a general rule that thin and sickly animals are dull of colour, while healthy ones are brighter of hue. He thought that natural selection plays a part here, for the stronger male will win a mate more easily, and, being strong, he will also be beautiful.

Wallace also drew attention to the beauty of certain fruits—black elderberries, blue sloes and bilberries, white mistletoe-berries. The colour of these fruits attracts birds, he suggested. The birds eat the soft parts of the fruits and scatter the seeds. Other fruits, certain nuts, for example, are green, and so are hidden from the eyes of birds; some, like the chestnut, have a further protection in the form of prickles.

As a rule Darwin and his followers simply discussed the causes which had led to the differences between male and female. They did not delve any deeper into these problems of sex. Such differences are, in the first place, differences in the constitution of the sex glands and the actual reproductive organs, and, secondly, differences in coloration, marking, and size of body, as well as difference in instincts. The first group include the so-called 'primary sexual characters', while the second include all the 'secondary' characters. When Darwin discusses animal beauty he deals almost entirely with these secondary sexual characters; some biologists, however, believe that these are entirely due to the influence of the primary sex glands. They think that the development of the colour, markings, horns, antlers, and other characteristic 'mascu-

line' adornments are due to secretions of the male glands, while these glands also inhibit the development of the corresponding feminine qualities. The female glands have exactly the opposite effect. These workers point out that castrated animals often exhibit certain characters which are usually only found in the opposite sex. Some investigators have held that the male is a more highly developed (advanced) form than the female (Jäger and Eimer have called this 'male prepotence'). Others have favoured the opposite view—that the female is a degenerate male. This is a development of the old idea, due to Aristotle, that the female is the embodiment of matter, the male the embodiment of form. The female, they asserted, was originally at least as beautiful as the male; but it expended so much of its energy in providing nutriment for its eggs and in caring for its young that it gradually degenerated.

There were others who believed that the striking and beautiful male represents a sort of sacrificial offering intended by Nature for the enemies of its kind; in this way the less conspicuous female would be protected, and so the increase of the species would be secured.

All this will serve to illustrate the way in which men speculated upon the beauty of plants and animals. It is plain that both Darwin and certain of his opponents thought of natural beauty as a homely countryman might think of it—bright colours, crude and glaring decorations, horns, antlers, long feathers, crests, &c., &c.—in short, all the unusual and striking features of the natural world. All their theories refer to details of this kind—and they pay no attention to that truer and more subtle beauty which reveals itself in fine though inconspicuous markings and shadings, in beauty of line, in harmony and in contrast of colour, in movement, in song, &c., &c.

Those who opposed the Darwinian theory recognized to the full the weakness of these attempts to derive the beautiful from the merely useful. The Duke of Argyll attempted to show that there are definite aesthetic laws underlying many of the appearances in the realm of nature,

and that these beauties are not there simply because of their usefulness.

Every now and again some investigator would affirm that beauty has an objective value.

Brunner von Wattenwyl, a Viennese entomologist, examined the coloration and markings of certain beetles, and declared that the whole arrangement, with its definite lines, circles, and the like, follows definite aesthetic laws, and is not determined by morphological ones only (1873). Suppose the markings were really determined by morphological characters, the thorax of the beetle would be differently marked from the wing-covers, since these two structures are not of the same morphological nature. Some beetles, however, are marked in circles, one half of each such circle being on the thorax, and the other on the wing case (elytra). This arrangement can only be explained by reference to some aesthetic law.

Brunner quotes other examples of the same phenomenon, and asserts that every organism embodies a principle of perfection, and that the beauty of the organism is merely an expression of this principle.

These views, expressed by Brunner, were not very sympathetically received; nor was the work of Hallier, the botanist, on *The Aesthetic Motive in Nature* (1890). This book is lengthy and tedious, but in it he points out certain facts that had hitherto escaped observation; that plants, for example, usually have a pleasant smell, while animals, as a rule, have an unpleasant one; that the foliage of plants bearing blue flowers is never a full green, but always a bluish or yellowish green; that we can deduce certain definite aesthetic laws from a study of the distribution of colour in Nature, &c., &c.

The colours of flowers do not merge into one another; there are two definite series; one, the xanthophyll series, range from white through yellow and orange to red; the other, the anthocyanin series, pass from white, through pale blue and deep blue, to violet. Related forms have colours belonging to one or other of these series, to which

our attention was first called by de Candolle. Very little work has been done on this subject, and it would be worth while to examine this classification more closely.

Those who have studied beauty from the aesthetic point of view have not protested against this attitude of the scientists, which banishes all belief in objective beauty in Nature. They promulgate certain generalizations about beauty in Nature, and then proceed to discuss beauty in relation to the works of man—that beauty which man produces in imitation of Nature. If we attempted to gain some idea of Darwin's real attitude to Nature from his theory of the beautiful, we should be tempted to believe that he had no real sense of natural beauty. We should be quite wrong in this conclusion, however. His theories about beauty may seem to us to be superficial, but his interest in the beauty of Nature is always delicate and human:

> 'I used to like to hear him admire the beauty of a flower; it was a kind of gratitude to the flower itself and a personal love for its delicate form and colour.
>
> 'I seem to remember him gently touching a flower he delighted in; it was the same simple admiration that a child might have.'[1]

This is how his son pictures him for us. He tells us that Darwin, when quite an old man, still kept a keen look-out for birds' nests, that 'he sometimes showed a tendency to strong expressions'. He describes, in the *Origin*, a larval cirripede 'with six pairs of beautifully constructed natatory legs, a pair of magnificent compound eyes, and extremely complex antennae'. 'We used to laugh at him for this sentence,' his son tells us, 'which we compared to an advertisement' (*Life and Letters*).

[1] *Life and Letters of Charles Darwin*, vol. i, p. 117.

X

MIMICRY

THERE are many ways in which living organisms may resemble one another. When alike in bodily structure we say they are related and call their similar parts *homologous*. Where parts are merely similar in function we say they are *analogous*. Lastly, organisms may be similar *in habit*, thus the lime and chestnut, the fir and larch, are of similar habit, while the bushy poplars have a habit quite unlike that of the pyramidal poplars. It is not customary to speak of similarities of habit among animals, but examples may be found among them too. Thus the 'swallow-tail' butterfly is much like the humming-bird in appearance and in its characteristic flight, while the habit of the shrew is like that of the mouse, that of the ostrich like that of the giraffe.

Such resemblances may, however, be only accidental. We may, then, ignore them, and define homologies as resemblances which affect the fundamental structure, while analogies are more superficial likenesses which are, so to speak, superimposed upon the homologies. Yet the effect of analogies may be far-reaching too. The fin of the whale, which is analogous to that of the fish, is merely an external modification of the mammalian limb, and its internal structure is determined by the fact that the whale is a mammal.

Other resemblances occur which are even less intimately connected with the nature of the organism. They do not concern the plan of the body, nor are they dependent upon the functions of its various parts, but relate to such apparently unimportant details as the external shape, coloration and markings, to certain bodily habits, and the like. Animals and plants which have very different morphological characters may be similar in appearance, even in the smells or the sounds they emit, and it is diffi-

cult to ascribe these similarities to mere chance. We say then that they are 'imitative', and the phenomenon is called 'mimicry'. There has been no attempt to analyse the widely divergent phenomena included under this head, no attempt to deduce the laws of mimicry. Hence we must fall back upon a purely empirical classification, which merely serves to illustrate how varied these devices may be.

1. Two species of the same order may be 'imitatively' alike in their bodily workings—the butterflies belonging to the *Leptalideae* resemble those of the *Heliconideae* in colour, marking, and shape of body. The two snakes *Python amethystinus* and *Dipsadomorphus irregularis* belong to widely divergent groups, and yet are almost identical in appearance.

2. Animals belonging to different orders may resemble each other: certain butterflies (*Sesia crabroniformis*) and certain wasps (*Vespa crabro*) for example. In the fly *Volucella bombylans* two varieties are distinguished. The larvae of this fly are parasitic on humble bees. In one type the larva lives on *Bombus muscorum*, and the mature animal is like this bee, while the other resembles *Bombus lapidarius*, in whose cells it is nursed through its larval stage. The wasp *Mygnimia aviculus* is very much like the beetle *Coloborrhombus fasciatipennis*, &c.

3. Animals, in their marking, may simulate their surroundings. The leopard and the jaguar have black eye-like spots on a yellow skin. Lubbock suggested that these give the dappled effect of the splashes of sunlight which fall on to the tree-trunks through a canopy of foliage. The tiger's stripes resemble the bars of light and shade among tall jungle grasses. Insects show this sort of mimicry particularly well. Some dragon-fly larvae cover their bodies with slime, and so cannot be seen against the background of the pond bottom where they lie in wait for their prey. Some night-flying butterflies, which lie concealed among lichens, are coloured greenish-white like the lichens. Many more examples of the same type of mimicry might be given.

4. Some animals do not mimic their surroundings, but exhibit sympathetic coloration; thus the lark, which is grey like a clod of earth; or the grass-green grasshopper. Arctic creatures are apt to be white. They may retain this coloration throughout life, or they may change it with the seasons. Other animals can alter their coloration, suiting it to the colour of the environment. The pupae of certain butterflies (*Pieris*) are differently coloured according to their surroundings. An analogous phenomenon has been observed among certain lizards, which after each moult adapt their colour to their habitat, but when the skin has once hardened the colour is fixed. The tree frogs can alter the intensity of their green coloration to tone with that of the surrounding foliage. Chameleons and many sea animals change their colour with the environment (cephalopods, crustaceans). The lack of colour seen in many sea and freshwater animals renders them almost invisible in water.

Among birds this imitative resemblance is also shown in their eggs, which often resemble their ordinary surroundings. Eggs laid in darkness—those of the woodpecker, for example—are white, while those laid in open nests are speckled green or brown. Certain birds which lay in sand have sand-coloured eggs.

5. Animals have instincts which enable them to increase this resemblance to the environment. The partridge hugs the earth. The green grasshopper chirps from a green bower. The sharks lay brown four-cornered eggs, the corners running out into four long thin bands; these eggs mimic the seaweeds on which the shark suspends them.

Some investigators regard simulation of death by certain animals as mimicry; that animals which visit flowers often resemble flowers in colouring is probably a related phenomenon; butterflies, blossom-inhabiting beetles, hummingbirds are among the most beautiful of animals.

6. Mimicry is exhibited not alone in form and colour but also in smells. There are plants which emit a corpse-

like odour by which they attract flies, and beetles which smell like roses or like musk, and there are many other well attested cases.

7. There is also mimicry in the world of sound; the yellow-hammer, particularly certain steppe varieties, chirrups like a grasshopper, and some lizards emit similar sounds. The song of one bird may be like that of another.

8. Plants exhibit mimicry as well as animals. The alga *Caulerpa* has organs which recall the root, stem, and leaf of the higher plant. Some plants have branches which look like leaves. The inflorescence of the Compositeae is like a simple flower. A species of *Mesembryanthemum*, which grows on the South African Steppe, has leaves closely pressed down on to the earth, which resemble stones. The flowers of orchids may imitate flies, bees, spiders, &c.

It has not been determined how common mimicry is, nor how it is distributed in the plant or animal series. It is not entirely unknown even among the lowest forms of life, as the Protozoa and Coelenterata; but it is commonest among the most mobile animals, especially the Arthropods and the Vertebrates. We have shortly enumerated the chief types of mimicry, using that word in its widest sense. Not all the cases alluded to would be regarded by Darwinists as examples of mimicry. They look at the matter from the utilitarian point of view, and consider only those devices mimetic which are useful to the animal in its struggle for existence.

This view has a history. Darwin's grandfather had already pointed out that some animals are able to hide from their enemies because of their colouring (Erasmus Darwin, *Zoonomia*, 1794). This phenomenon was often referred to, and in 1862 was studied more thoroughly by Bates. He noticed that certain butterflies of different orders are strikingly similar, and he assumed that these similarities were only to be explained by the Darwinian theory. One of the butterflies has a nasty taste, but the other is palatable to birds. Since, however, the palatable resembles the unpalatable form, the birds do not pursue

it. In the view of Bates ('Contributions on the Insect Fauna of the Amazon Valley', *Trans. Linn. Society*, xxiii, p. 495) the two butterflies chanced originally to be somewhat similar in appearance. Birds could distinguish between them and hunted the edible forms. Among these there would be some which were particularly like the inedible ones; these would be less preyed upon by the birds, and so would tend to survive. From among their offspring those most closely resembling the unpleasant-tasting butterfly would again survive, and so in the course of ages the similarity seen to-day has arisen.

Bates gave the name of *mimicry* to this type of resemblance. Darwin accepted the observations and explanations of Bates, and mimicry became one of the chief arguments for the evolutionary theory.

Other possible explanations of mimicry were ignored. The suggestion made by M. Wagner (1880), for example, that animals are forced to choose environments which they in some measure resemble, by their desire to maintain themselves alive: or the hypothesis due to Cope and Brunner that the qualities of animals, like those of the chemical elements, are not infinite in number.

The Darwinians thought that protective mimicry should be distinguished from aggressive mimicry; the former helps the animal to hide from his enemy, the latter enables him to make himself invisible to his prey. Wallace would also distinguish between two further types of coloration and marking. Firstly, there is warning coloration, which is hardly mimicry; indeed, it is the antithesis of it, as in the brilliant colours of inedible caterpillars. Secondly, there are the distinguishing marks by which animals are supposed to recognize one another. Wallace suggested, perhaps rather fancifully, that the white spot on the rabbit's upward-curving tail serves as a signal to the young when the mother, scenting danger, flies to her burrow. The white spot on the tail marks out for the young the line of retreat.

To-day we do not think this subject of mimicry as

important as they did in Darwin's time. The German zoologist Eimer (1889) and the Dutch lawyer Piepers (1903) early assumed a sceptical attitude. They pointed out that the chasing of butterflies by birds is not as everyday a phenomenon as the theory would suggest. Piepers lived for twenty-eight years on the Island of Sunda, and states that only on four occasions during the whole of his sojourn there did he see a bird chasing a butterfly. Other naturalists have expressed similar doubts, though there are some who have collected facts which seem to support the opposite conclusion. While this uncertainty exists as to how far there *is* any hunting of butterflies by birds, it is obvious that inferences concerning mimicry which depend upon an alleged chase can by no means be regarded as established.

There are other cases, e.g. the case of the two similar snakes referred to above, where the mimicry cannot possibly be protective, since both forms are equally liable to be attacked by enemies. Piepers also doubts whether the butterflies which were assumed to be inedible by birds are really so unpalatable. Moreover, he cites many cases of very close resemblance between butterflies which inhabit quite different areas. Some butterflies from the Cameroons are extremely like certain European forms, some from Natal like others from Siberia, and so on. But butterflies are, as Eimer points out, closely related to each other. Their bodily organizations are similar, and the markings develop in accordance with that organization. Hence these resemblances have, according to him, arisen by chance.

Animals may repeat the colour of their surroundings in their skin colouring, they may 'photograph' it, in short. Eimer held this to be the explanation of many phenomena called mimicry. Piepers, in agreeing, further expressed the view that mimicry may be due to some suggestive influence exerted upon the organism by its surroundings, may be a psychological phenomenon, in short.

The views of these and of other sceptics caused a

revolution in our ideas about mimicry. Formerly too much attention was devoted to the subject, now it receives too little. The phenomena are so numerous and occur in such manifold and striking forms that we cannot believe they are all due to mere chance resemblances. To study mimicry we need not go far afield, for the phenomenon is common enough in Europe, especially among insects.

To the historian, the modern point of view about mimicry is of great interest. We do not doubt the existence of homologies and of analogies. These ideas arose from a full examination of the facts. They come to us from pre-Darwinian days, and would remain even if Darwinism were abandoned. The ideas about mimicry, on the other hand, were introduced into biology as the result of the evolutionary theory. Darwin and his followers did not endeavour to ascertain what mimicry really is—they were opposed to any abstract analysis of the phenomena of mimicry. They picked out striking, but isolated, examples, and then propounded explanations to which they attached great weight.

XI

PROGRESS AND DECAY

THE belief in progress—in a humble past, a better present, a still more glorious future—has become so much a part of our mentality that it is difficult to imagine a time when this thought was unknown. And yet Rousseau earnestly sought for facts to combat the idea that classical culture was higher than our own. On the threshold of the eighteenth century we find Fontinelle (1708) pursuing the same quest. Only the late eighteenth and early nineteenth centuries brought the conviction of continual progress. Herder was among the pioneers of this movement. Hegel's influence was even greater. He taught that in the world of events there is progress from unconscious beginnings to conscious understanding, and that this development is the most important subject of philosophical study. In France, Condorcet and Comte were responsible for the spread of the belief that the human mind progresses: it begins with theological conceptions, and passes on through metaphysics to science. In England, two years before the *Origin of Species* appeared, Buckle had analysed the progress of civilization. From Cuvier and Lamarck onwards biologists had been depicting a world which was originally inhabited by the simpler forms of life, and describing how these grew more complex, step by step, until Man was reached. Agassiz, in particular, wrote much on this theme. So too von Baer, in his work on embryology, referred to the progress revealed by the study of development, and showed how the gulf between the various types widens as development proceeds. Milne-Edwards expressed the same idea in a somewhat different form; he believed that progress meant that, in the living hierarchy which is a body, there is an ever-increasing division of labour, both structurally and functionally.

Thus Darwin entered a world in which these ideas were

rife. The philosophy of Mill, the ideas of democracy, the history of man, the discoveries of palaeontology, the belief that there is progression displayed in the various series of animals and plants—all were witnesses pleading the same cause. Darwin's teaching really represents a slight reaction against this belief, not because he rejects the idea of progress, but because he points out that progress is not inevitable, that there may be stagnation or even retrogression.

The word 'evolution' is often taken to mean progressive evolution, but Darwin himself understood by it merely a continuous change. He pointed to the parasites to show that this change is not necessarily progressive. They were more complete and perfect as independent organisms, and they became degenerate and simplified when they adopted a parasitic life. He also pointed out that the advance of one organ of the animal body often entails the degeneration of others. Thus many animals, and even man himself, possess organs which are in decline, as well as some which are very highly developed.

Darwin's theory was a very empirical one. Consequently the connexion between it and those ideas of progress which were so prevalent was not clear. Darwin himself definitely rejected the theory that progress is inherent in the scheme of nature, and declared that such progress as occurs must be due to definite processes at work. Hence the Darwinists did not accept any of those theories which assume that evolution is identical with progress. On the other hand, to those who were antagonistic to all such ideas, they pointed out that the facts of palaeontology and embryology prove that progress does most certainly occur in Nature.

The same material was used by the anti-evolutionary school however, to prove, firstly, that Nature progresses and evolution proceeds according to a pre-ordained plan, and, secondly, to show that progress in the Darwinian sense is not proved by the facts of palaeontology. Hence it came about that two investigators, holding diametrically

opposite views, appealed to the same facts in argument. In 1862, for example, Huxley was affirming that the facts of palaeontology support Darwin's views; a year later O. Volger, working on the same material, claimed that the fossil records do not reveal any continuous progress, since even the oldest rocks contain some fairly advanced forms.

Haeckel made great use of the idea of rudimentary organs. He forgot that De Candolle had built up the greater part of his idealistic morphology upon the assumption that there are such organs, and thought that this idea of rudimentary, and hence purposeless, organs originated with Darwin! The idea seemed to Haeckel to be extremely important, for it apparently disproved the assumption that in Nature a definite purpose is revealed. Haeckel therefore called the study of such organs and functions *Dysteleology*.

The custom arose of calling whole animals and plants 'degenerate'. They were presumed to have sunk from a higher to a lower plane of existence. It has been very definitely asserted that parasites are forms which have adapted themselves to a less complex way of life, but apart from this group few naturalists have believed that there has been any widespread degeneration among animals. Dohrn was, however, an exception. He tried to prove that the lower fishes have arisen by degeneration from the more advanced forms; that the coelenterata and the protozoa are both degenerate groups (1875).

In the literature the word 'degeneration' is not always used in the same way. To Buffon, the French biologist, it meant merely a change of form. The French psychologist, Morel, used the word *dégénérescence* (1857) to describe any 'pathological departure from the original type. No matter how simple the departure may be, when once it has arisen it is extremely infectious. Any one attacked in the slightest degree will gradually lose the power of playing his part in human society. All hope of mental progress is endangered, not only for him but for his descendants'. (B. A. Morel, *Traité des Dégénérescences*,

1857.) Thus a new variety of the human race may arise, but it is a variety doomed to speedy extinction. Degeneracy in the human race is to be recognized by certain bodily signs: lack of symmetry between the two halves of the face; the lack of ear muscles; squinting; harelip, and other so-called 'stigmata'. Lombroso and a French physician Féré were later to devote a great deal of attention to this aspect of degeneracy.

According to the Darwinian theory such manifestations are to be regarded as simplifications rather than as deteriorations. Darwin did not believe that some forms are better adapted to life, others less well fitted. Each species is suited to its own particular conditions, and some are more, others less, highly differentiated. He believed that the tape-worm, which has no head, no sense-organs, and no digestive tract, is as well suited to its environment as is the more complex free-living worm to its more variable surroundings. We cannot say whether Darwin was right. Are we to regard all the species which occur as 'natural'? Is it not better to look upon some as degenerate, or, to express it more forcibly, pathological? The idea of pathological forms is quite foreign to Darwinism. There is no place for any such in a scheme where the struggle for existence sees to it that only the fittest survive. The word 'abnormal' has no meaning in the Darwinian philosophy, for, according to that, everything that exists is normal.

There has been little further investigation of this question of abnormal species, though it is often assumed that such exist. Virchow asserted (1886) that there are pathological races (bulldogs and pugs for example), as well as pathological genera and species; he gave examples from among the parasitic Crustacea.

Another discussion of this question of the occurrence of abnormalities, is found in the work of von Kennel (1901). He directs attention to the horned hog of Celebes (*Babyrussa alfurus*), which has long curved upper canines which pierce the upper lip; to the narwhal, with a long

tusk curved like a corkscrew; to *Anarhichas frontalis*, a New Zealand bird with a beak the apex of which is bent to the right at an angle of 30°. The whole question deserves more thorough study. It seems possible that the large mesozoic reptiles, that such structures as the peculiar outgrowths on the heads of some insects, that all species which are either abnormally large or abnormally small when compared with the average, are in a sense pathological. A new philosophy must prevail, however, before such problems can become the subject-matter of science.

Biologists and non-biologists alike have been more concerned to suggest the causes of degeneration than to study the subject itself. Weismann, however, did important work in this field, and aroused great interest. His thesis was that the struggle for existence is the only force making for progress. Directly it ceases the whole organism, or some part of the same, begins to degenerate.

There were various other alleged causes of deterioration. Among these the pairing of nearly-related individuals was the chief. C. K. Sprengel drew attention to this question as early as 1793, when he showed that even in hermaphrodite plants there is very often cross-pollination. Earlier students of mental disease, Esquirol and Spurzheim, for example, had also asserted that the marriage of near relatives often leads to degeneracy in the offspring. Diverse diseases were said to result from such marriages—sterility, monstrosities of all kinds, harelip, albinism, scrofula, apoplexy, epilepsy, idiocy, goitre, paralysis, blindness, deafmutism.

Darwin once more turned the attention of biologists to this problem. His views were not as extreme as those of Esquirol, but he asserted that the mating of individuals who are rather different from each other is advantageous for their offspring.

It is now apparent that inbreeding is not as dangerous as was once thought. Facts have come forward indicating that mating of near relatives is not dangerous, except in

so far as family failings appear intensified in the off-spring.[1]

Another suggestion has been made that, when organisms are degenerating, they follow the same order in their decay as they did in their development, degenerative processes following the biogenetic law in the reverse direction. The zoologist Lameere and the psychologist Ribot were among those who favoured this view, but it did not lead them to any very striking results.

Outside the realm of biology the idea of degeneration became firmly established. Psychologists, students of race, lawyers, novel writers—all referred to it. Zola introduced it into the novel, Ibsen into drama, and Max Nordau into literary criticism, the latter developing it to absurd lengths.

[1] See L. Woltmann, *Politische Anthropologie*, Eisenach and Leipzig, 1903, pp. 105 sqq., which gives the different views that have been held about this matter.

XII

ERNST HEINRICH HAECKEL

Character.

ERNST HEINRICH HAECKEL was born at Potsdam in 1834. In his youth his favourite books were the works of Humboldt and Schleiden. He studied medicine under the best teachers of his time and attended Alexander Braun's botanical lectures. In these the cell theory, the facts of development, and a somewhat idealistic morphology were presented in a philosophic manner. Müller's lectures on physiology were equally philosophical, and Haeckel attended those too. At Würzburg his teaching was more 'modern'. Leydig and Kölliker were laying the foundations of modern embryology and histology. The more old-fashioned naturalistic philosophy meant nothing to them; it merely awakened youthful memories. In Würzburg Haeckel heard Virchow's lectures on *The Cell*; these provided new material in support of the cell theory, and presented it in an unmistakably materialistic light. Leaving Würzburg, Haeckel went to Italy, where he nearly became a landscape painter! He was still, however, unconscious of any special bent. In Sicily he called to mind the encouragement given to him by Johannes Müller, and threw himself into the study of the Radiolaria. In 1862 he published a large monograph upon them, in which he mentioned Darwin's theory with approval. The next year, at a congress at Stettin, he took up arms for the theory. From then onward he devoted all his energies to its establishment. Completely under its sway, he wrote with his friend Gegenbauer a two-volume book: *General Morphology*. This was intended to win over German biologists to Darwinism. The attack, however, did not succeed. The German professors treated the book as a belated offshoot of the long

discarded Naturphilosophie, and paid little attention to it.

Disappointed with this want of success in the intellectual world Haeckel determined to appeal from the academic class to the public. Taking the advice of friends, he published a work, *The Riddle of the Universe*, which was extremely successful, and probably did more than any other book to spread the Darwinian theory. It went through ten German editions and was translated into eleven different languages, including English. Haeckel was now famous.

Haeckel was upright and full of energy, but blunt and harsh to opponents. The world of science was for him a battle-ground, and every word of his was an attack. He was a great contrast to the tranquil and learned Darwin or the elegant and critical Huxley.

Men like Haeckel are born only in Germany—the blood of Luther, Bismarck, and Nietsche flowed in his veins. Looking for a man of similar temperament we should select Fichte, the protagonist of the freedom of the German University. Fichte had no great breadth of vision but tremendous powers of persuasion. He said of himself: 'I have only one passion, one need, one desire—to influence others.' Fichte expressed, not only his own temperament, but that of all great prophets, including Haeckel, in the following words:

> 'You say a philosopher must remember that he is merely an individual, liable to make mistakes, and that he must be ready to learn from others. Do you know what sort of a person you are describing?—a man who, in his whole life, has never known what it is to feel absolute conviction.'

Haeckel shared this feeling. He was never shaken by doubt. No teaching altered his views. His belief in Darwin's theory underlay his every activity. His conviction was so strong that he allowed nothing to hinder him from proclaiming it. The scientific world ignored his fantasies. Darwin, the peacemaker, tried by letter to tone down his enthusiasm, but in vain. Huxley admonished him,

both publicly and privately. His German friends sought to dissuade him. It was all useless. Du Bois Reymond's humour left him unmoved. The indignation of His, Goette, Rutimeyer, Wigand, Semper, Claus, Loofs and others left him cold. He paid no attention to the blows aimed at him. To the end he remained the bold defender of Darwinism that he had been in his early days. He was a very prolific writer, and like a true German he liked long books. But whatever the ostensible subject of his book, his *ceterum censeo* remained the evolution theory. He would have set heaven and hell in motion to win *freedom* for science—freedom, that is, for scientists to preach evolution.

He turned his attention to the sea sponges. This resulted in a curious play with names, by which he endeavoured to prove that there are no species among the sponges, and hence that they provide a wonderful confirmation of the theory of evolution. When he wrote about Goethe he attempted to prove that he was in favour of evolution and a forerunner of Darwin. He rejected religion, for had he not a higher ideal—evolution! When Bismarck visited Jena, Haeckel suggested that they should honour him by giving him the honorary title of 'Doctor of Phylogeny'. Evolution is the life-blood of his books. Take away the ideas about evolution and nothing is left but a lifeless husk, a mass of high-sounding words, of dull descriptions, of many-coloured pictures—all empty and devoid of life. We look in vain for depth of feeling, for fineness of conception, for humour, style, self-distrust—in short, for any spark of humanity. If you read one book of Haeckel's you have read them all.

Yet he was, withal, a many-sided investigator. Most of his original work deals with a very theoretic and systematic classification of animals, but in his theories he ranges over the whole field of morphology and of embryology, and he partly surveys the domains of palaeontology and of Darwinian anthropology. He was the first to write a history of evolutionary theories. He published a large

volume on the beauty of animal forms. He was one of the pioneer students of the Plankton. He wrote on religion and on philosophy. But above everything he was a controversialist. He knows no moderation in his attacks on opponents. He combats Church dogmas and upbraids those who reject the theory of evolution and his ideas about embryology—or he praises Darwin and his so-called forerunners, Goethe and Lamarck. But whether he is attacking or whether he is praising, there is nowhere any evidence of deep thought, nowhere any suggestion that he has arrived at his convictions after an inward struggle, nowhere the slightest attempt at real understanding either of friend or foe. We only see how actively he wields his axe against his foes, and how greatly he overestimates his friends. He compares Darwin with Copernicus! In another place he says that Lamarck is the Copernicus of biology and Darwin its Newton. He says that no one who has a sound judgement and some small knowledge of the subject can help agreeing with his monistic views. With a *naïveté* only equalled by the credulity of his hearers, he asserted that biology had not been a science at all before the time of Darwin; only then had there begun any 'exact thinking' on biological subjects, only then had 'the almost complete lack of really thoughtful, comparative observation' been remedied. Haeckel believed that the doctrine of evolution was definitely proved, as also that men have descended from monkeys; the occurrence of rudimentary organs provides incontrovertible evidence. The theory of Natural Selection he regarded as the most wonderful discovery of the modern intellectual world.

The desire to inspire his reader with an absolutely definite conviction of the truth of his views led Haeckel to love new words, as if every new word represented a new thought! Some few of the words he introduced were accepted, e.g. ontogeny, phylogeny. The great majority were stillborn.

Haeckel's views.

When writing his *General Morphology* Haeckel was still under the influence of idealism: we see this in his postulate that biology admits of exact mathematical treatment. He was looking for 'the stereometric plan of the organism; knowledge of this is as important for the organic morphologist as is a knowledge of crystallography for the student of inorganic form'. Following in the footsteps of Bronn, he discussed the 'axes' and 'poles' of the organic body; distinguished between those which have no axis (volvox), those with many axes (regular and irregular), and those with one axis (with equal poles and with unequal poles). He even wrote of 'hemihedric' animal forms, and was convinced that all these forms could be explained as resulting from purely mechanical causes.

Afterwards he abandoned these extremely mechanistic views of morphology, and came to disagree with His and Goette, who had tried to explain embryonic development on mechanical principles. Their explanation seemed to him 'too coarse and *mechanical*', and contradictory to the theory of evolution. For has not every organ a long history? Has it not reached its present form after uncountable centuries, during which it has undergone innumerable modifications to fit its changing environment, and during which inheritance has continually played its part?

It is useless to seek for an *a priori* explanation of the fact that Germans inhabit Germany and Frenchmen France. The cause is historical. In the same way, said Haeckel, only in the study of the past can we find the clue to the secrets of animal structure. He declared that phylogeny, the study of the relationship between animals, is not an exact science—it is history. The study of evolution is the goal of all human knowledge, the principle underlying all philosophy, the key to every problem, the answer to every question. 'Development is now the magic word by means of which we shall solve the riddles by

which we are surrounded, or at least move along the road towards their solution.'

'Every being can only be truly known when we know his becoming.' Thus morphology, the study of the architecture of the animal body, became 'morphogeny', the study of the evolution of one form from another; physiology became 'physiogeny', a study of the development of function, and of the ontogeny and phylogeny of that function. The evolution of speech, of the upright position, of human culture—all these, according to Haeckel, are problems of physiogeny and of physiogeny only. Our study of man must become 'anthropogeny'—the study of his origin from animal ancestors.

Regarding evolution, Haeckel formulated certain general laws. The first and most fundamental law of Nature deals with causation. 'According to this highest of all laws, everything that is, has been, or is to be, arises as the necessary result of many contributory causes, and each result becomes in its turn a factor, leading with absolute inevitableness to new results.' Down with ideas of expediency, down with vital force; away with the conception of a world of moral law, with any idea of the freedom of mankind! The universe is but a great machine, in which the vibrating atoms are the wheels. Here they are massed together to form a glowing sun, there to form a tiny beetle; here to drive the planets through the universe, there to make man behave like a free and thinking being. There is no fundamental difference between the living and the non-living, for all the elements found in living matter are found in the non-living also, and organic compounds can be artificially produced. Nor is there any fundamental difference in bodily structure, for lifeless crystals have a definite form, just as have some living organisms, while the simplest organisms possess, like flints, no form of their own. The organic and inorganic worlds alike are dominated by two forces, attraction and repulsion between atoms. Molecular motion is the cause of all things—even of the soul.

'We understand by "soul" and the "soul's activity" a member of excessively complicated reactions of the central nervous system; the most important are those called "will" and "perception". The will, which lies at the root of all voluntary motion, and perception too, are phenomena which only occur in the well-developed nervous systems of the higher animals: they are complicated molecular movements in the ganglion cells of the central nervous system.' Little wonder that Haeckel found such a soul in the one-celled animals, nay, even in plants, for, according to him, plants carry out the same physiological processes as do animals. 'Yes, every atom must have a soul, for it possesses some energy.' Sympathy and antipathy, desire and aversion, attraction and repulsion are psychic qualities 'experienced by all atoms'.

Haeckel explains the evolution of organic beings in the following way:

Creation by God is unthinkable and contrary to all experience. Nothing then remains but for us to believe in the spontaneous generation of the simplest forms of life, and that out of these all the others have arisen in the course of evolution and at the call of Natural Selection. At first, from lifeless matter there crystallized out non-nucleated cells—monads—and every animal type now existing had some sort of monad for its original ancestor. From one type came the vertebrates, from another the coelenterata, from yet another the diatoms; one molecule more or less of carbon, sulphur, or phosphorus was the only difference between the first forms of life on this earth. But eventually the earth became green with plants, and then followed the animals.

Haeckel's Relation to Darwin.

Haeckel turned all work which was inspired by Darwinism into new channels. Darwin's method of proof appeared rather strange to the continental scientists of his time. They studied morphology, embryology, palaeontology, classification, the cell theory. Darwin laid emphasis

on Natural Selection, on the 'struggle for existence', on inheritance, variation, and the details of geographic distribution. He supported his assumptions by facts drawn from the records of animal breeders and from annals of gardening. He discussed the ancestry of pigeons, rabbits, and dogs, made experiments on the resistance of seeds to fresh and salt water respectively, and collected evidence from books of travel and similar somewhat inexact sources. Darwin hardly touched biology as biology was understood on the Continent. In the 400 pages of the *Origin of Species* he devotes four and a half to morphology and ten to embryology, while the cell theory is hardly mentioned.

Haeckel, on the other hand, did not study variability, hybridization, racial problems, the facts of distribution, of heredity, or any allied subject. He thought that the whole problem could be summed up in the two words—Adaptation and Inheritance. Adaptation leads to the creation of new types, while inheritance leads to their fixation. Thus Haeckel included under these two headings the whole of Darwin's book, save a single chapter. This chapter deals with 'Mutual Affinities of Organic Beings; Morphology, Embryology, Rudimentary Organs'. Haeckel made this chapter the point of departure for his own investigations, and so, at the end of last century, gave a new direction to the whole of biological research. This new school did not attempt to examine Darwin's premises; but classification, morphology, and embryology were directed into evolutionary channels. It was thus that Haeckel arrived at his own concrete theories, at his teaching about phylogeny, at the 'Monera', at his 'Fundamental Law of Biogenesis', at the 'Gastrea' theory.

Phylogeny.

From the eighteenth century onwards it had been believed that the quintessence of an organism is revealed by its form and structure. This idea was held by Linnaeus, Cuvier, de Jussieu, de Candolle, Geoffroy, Goethe, and all the idealists. There were, it is true, some philosophers

whose explanations were developed along other lines. Lamarck believed that life reveals itself, not so much in bodily structure as in its strivings, its desires, its contact with the environment, and so on. Oken attempted a physiological classification of animals, but neither his work nor Lamarck's was generally accepted.

Darwin took up these ideas anew. He again asserted that the animal is characterized, not by its form but by its method of life, and that all the qualities of living organisms are the direct result of their interaction with the environment. It was, therefore, natural for him to devote little attention to morphology. His attention was focused upon the conditions under which life exists, and when he put forward what he believed to be a higher view of Nature it was certainly a more novel one. He tells us how the old conceptions aroused by such phrases as 'a vertebrate animal', 'a mammal', 'a species', 'unity of plan' disappeared. They were replaced by new pictures, as the animal in its greedy search for food, the universal struggle for existence, interbreeding between organisms. With these new colours Darwin repainted the face of Nature.

Haeckel did not attain to Darwin's vision, but he was full of enthusiasm for Darwin's pictures because of the newness of their colours. These colours alone attracted him, and remaining faithful to the older conceptions of science he spent himself in introducing a new nomenclature more consistent with the doctrine of evolution. Phylogeny and evolutionary morphology were begun by Haeckel and Gegenbaur; they still contained the ideas of the older morphology, but these ideas were expressed in new terms.

If we listen to Haeckel's words we find this difficult to believe, but his deeds make it perfectly obvious. First of all, hear his words.

'All the facts concerning the morphology of any organism, concerning its anatomy and its development, the tectological as well as the promorphological facts of its anatomical structure—all these are the inevitable out-

come of forces which work according to definite mechanical laws' (*Generelle Morphologie*). This suggests that if we could only study those mechanical forces, if we could visualize their action, our vision would develop into a picture of the organism. Haeckel made no attempt to do this, however. He gave us not the faintest clue to the mechanism that could produce an amoeba, a moneron even, still less a man. We cannot discover these 'mechanical causes' with the aid of the microscope, the scalpel, or even by philosophy; and these were the methods of study which Haeckel had taken over from his teachers—the idealistic morphologists.

Apart even from this, we can trace the influence of his predecessors in the words quoted. Haeckel points out, it is true, that 'physiology and psychology will have to receive genetic explanations'; in practice, however, he only applies his explanations to the facts of morphology and embryology, the two branches of biology which were being actively studied at that time. In this new 'Darwinian morphology' of his he does not suggest that two animals, or two plants, are related because they have been formed by the action of the same mechanical forces, nor because they have been acted upon by a similar environment, but because their structures, both as embryo and as adult, are similar. Is not this the method of Cuvier, of Goethe, of Geoffroy—the old 'comparative method'? Haeckel used all these ideas, nor did he endow them with any wider meaning, though he asserted that 'relationship' had only meant 'similarity' in the past, and that, if we follow Darwin's model, it will now signify a true blood-relationship.

Homologous organs, Haeckel said, were, according to the earlier view, merely those which were similar in structure, while analogous organs had similar functions. Now, he claimed, we look upon homologous organs as those which are descended from a common ancestral organ, while analogous organs represent similar adaptations to a common environment. But how does he recognize

these blood-relationships, these inherited and adaptive structures? Simply by comparative methods, just as formerly similarities, homologies, and analogies were recognized.

Haeckel called this morphology, redressed in a genetic terminology, phylogeny. Phylogeny is the study of the evolution in time of the various plant and animal races (Greek *phylon* = race). He admits quite openly that his phylogeny is nothing more than the old systematic biology.

Haeckel's phylogeny follows in practice the following fundamental rules. The nature of an organism is revealed by its form. By comparing both fully developed and embryonic forms we find that they have certain characters in common. We collect these characters and form an abstract whole, a plan. The animal which reveals this plan in its most elementary form is called the 'ancestor' of the organisms we are comparing, or is 'the type nearest to the ancestral form'. For example, a group of animals is found to possess a common character—they are all unicellular. The amoeba and the infusorians belong to this group, but the amoeba has no definite organs, while the infusorians possess certain specialized structures. Hence the amoeba more closely resembles the primitive animal form, and the ancestors of all animals were therefore like an amoeba.

This was how Haeckel drew up his genealogical trees—schemes of classification arranged in tree-like form, the lower parts representing ancestral types, the branches younger and younger descendants until, at the ends of the smallest twigs, the names of those animals presumed to be the most modern were written. Haeckel hoped by his genealogical trees to overthrow Cuvier's idea of 'types'. Cuvier taught that animals were formed on one of four definite plans. Darwin's theory had suggested another view: no longer were we to believe in a 'plan' for the animal organism; each animal was simply a collection of individual characters which had evolved in the course

of time. But the abandonment of this idea of 'types' was theoretical rather than practical. The Darwinians believed that 'types' exist, even as Cuvier had done, and Haeckel acknowledges this quite openly.

'Darwin had assumed that there are a few fundamental types in both the plant and the animal world—in each kingdom perhaps four or five such.

'In all our systems of classification we follow this idea. The 4–7 *phyla* or groups into which we still subdivide the animal kingdom are the groups which all zoologists have recognized since the days of Von Baer and Cuvier—they have been called "plans", "principal forms", "branches", "groups", &c., &c.' (*Natürliche Schöpfungs-geschichte*).

The construction of genealogical trees was a favourite occupation of Haeckel. Most biologists adopted this method, and it became the custom during the seventies and eighties of last century to close every systematic or anatomical investigation with a genealogical tree; this was either drawn or described in words.

Some condemned this method from the very beginning. In 1876 du Bois Reymond said that such trees would have about as much value in the eyes of posterity as has Homer's story of the pedigree of his heroes! Huxley, who first liked them, later rejected them. In recent times these genealogical trees have been quietly abandoned by most biologists, and Haeckel is held up to ridicule as if he had been the only sinner. Haeckel is also accused of having drawn up a genealogical tree for Man. We forget that Darwin drew up one in his *Descent of Man*; that Wundt published a tree showing the evolution of the sense organs; that Gegenbaur published one for the vertebrate limb, Romanes for the human soul, Spenser for social customs, Schleicher for human speech. Open any text-book of anatomy, of zoology, of systematic biology written in the eighties. If it has any pretence to be called scientific it will assume that Haeckel's ideal, the genealogical tree, is the final goal of investigation.

The Fundamental Law of Biogenesis.

The work of von Baer (1828) caused the idea that the organism, in the course of its individual development from the egg, passes through the lower animal forms, to be discarded by the biologists of the thirties and forties. They accepted Baer's idea, based on the philosophy of Aristotle, that development is merely an increasing differentiation—an advance from the general to the special. This conception is closely linked with the idealistic view of life. It affirms, for example, that in the human egg the whole man is contained as a potentiality, an idea; that, during development, this idea assumes a more and more concrete form until it finds its complete expression in the adult individual. When investigators adopted the mechanistic and materialist view of life they ceased to understand Baer's point of view.

Then there was a very extraordinary change. Von Baer was still a famous man; no one criticized his ideas about development. But he was famous as the discoverer of the theory of Meckel and Serres—the very theory that he had always opposed! It was Darwin who gave him this new fame.

It is true that there is a superficial resemblance between the two theories. Von Baer said that the embryos of different animals are alike because they are developing on the same plan. Meckel asserted that, as it develops, every animal passes through the (adult) phase of certain of the animals below it in the scale of existence. Von Baer compared embryos with other embryos; Meckel compared embryos with adult forms.

Darwin was probably the first to confuse the two views. In the *Origin of Species* he cites von Baer's statement that the 'embryos of mammalia, of birds, lizards, and snakes, probably also of chelonia, are in their earliest states exceedingly like one another' to prove his hypothesis that the animal, in the course of its individual development, climbs up its own genealogical tree. This view seems, it

is true, to be different from that held by Meckel, for it refers to the phylogenetically older, while Meckel's is concerned with the systematically 'lower'. But, used in this way, 'older' and 'lower' are merely two words for the same idea, and the difference is only an apparent one.

Darwin's view soon began to bear fruit. Sir J. Lubbock, a merchant with cultured tastes and a near neighbour of Darwin's, set out to prove that insects, in the course of their development from the egg, pass through stages representing their own phylogeny. He soon recognized, however, that this idea could not be applied to the butterfly group, for all the facts are against the assumption that the caterpillar was ever a fully developed organism.

The theory was applied with greater success, for a time at least, to the crustacea. The eggs of most crustacea, like those of butterflies, turn into larvae, and the larvae undergo many changes of form before the adult form is reached. Fritz Müller, a German teacher living in Brazil, examined the larvae of many crustacea, particularly that type known as *Nauplius*. He declared that this form does not appear in the larval stages of certain species, but that in those another larval stage occurs, the so-called *Zoea* stage. In his *For Darwin* (1864) he asserted that the Nauplius, the Zoea, and other crustacean larvae represent phylogenetic stages in the ancestry of the higher crustacea, and that from these we can see to-day what the ancestors of the modern crustacea were like; that, in short, the present-day crustacea repeat in their individual development the history of their race, though in an abbreviated form. In those forms in which the Nauplius stage is lacking, the process of development has become so curtailed that the Nauplius stage has been completely suppressed. Darwin appreciated the originality of Müller's work, and had it translated into English. Haeckel saw even more in Müller's method, and, following it, he evolved his fundamental law of biogenesis.

The Nauplius theory was not accepted for long. To-day the Nauplius is not considered of more value for

elucidating the phylogeny of the crustacea than is the caterpillar for throwing light on the evolution of the butterfly. If the Nauplius really represents an ancient form, out of which the modern crustacea have been evolved, then those crustacea with the simplest morphology should be most like the Nauplius—for the simplest should be the most primitive. But the structures that the simplest crabs have in common are more numerous than those they share with Nauplius (they all have, for example, segmented bodies). So that, according to this theory, the Nauplius must represent a more modern form than do the simplest crabs.

Before the Nauplius theory was abandoned A. Dohrn tried to make it more complete by adding the Zoea theory. He assumed that the Nauplius is the ancestral form of all crustacea, while the Zoea is the form from which the higher members of the group have evolved. But this, too, had soon to be abandoned.

By widening the application of the Nauplius theory Haeckel developed his general law. Every animal during its ontogeny—that is, its development from the egg to its final form—passes through the same stages as its race passed through in its evolution from the single cell. Embryonic stages, larval stages, and the like represent in the essentials of their structure features inherited from a time when the animal was less highly developed than it is to-day.

The law is only applicable to the more salient features of structure. The development of the embryo is very much shortened when compared with the evolution of the race; in a few hours or a few days it passes through a series of forms which took millions of years to evolve. Hence the ontogenetic story is very much simplified. The individual life-history skips many stages which occurred in the ancestral progress; others are much altered and curtailed.

Man is developed from a single cell, the fertilized egg. This shows, says Haeckel, that the human race has been

evolved from a single-celled organism. The human embryo develops, on the posterior portion of the sides of the head, rudimentary structures which resemble the gills of fishes; so Man must have been, once upon a time, an animal that breathed by gills.

On the other hand we cannot, from the fact that the human embryo is united to the uterus by the placenta, infer that some fully developed organism once bore a placenta. This organ represents an adaptation of the embryo to life *in utero*.

Haeckel called those embryonic organs which represent ancestral characters and have a phylogenetic significance Palingenetic (Greek=*again produced*); those which represent recent adaptations to embryonic life, &c., are Caenogenetic (Greek=*recently developed*). As we follow the development of the embryo we must distinguish between the palingenetic and the caenogenetic features. The former tell us the history of the evolution of the organism, the latter how the animal and its embryo have been gradually adapted to new conditions. 'Ontogeny', says Haeckel, 'is a brief and incomplete recapitulation of phylogeny.' If this be true we should be able to deduce the history of any living form from the study of its ontogeny. All that we have to do is to learn to distinguish between the palingenetic structures and the caenogenetic ones. Haeckel formulated the following rules for our guidance:

(1) The earlier an organ appears in the life of an embryo the older it must be.

(2) When comparing any series of embryos or larvae we shall probably find they have certain characters in common. The more varied the adult types which have the same common embryonic structure the more likely is it to be true that the structure is one derived from a common ancestor.

This was the method by which Haeckel attempted to provide embryology with a new terminology. An examination of his biogenetic law will convince us that it could not lead us very far. For how does Haeckel seek to dis-

tinguish between palingenetic characters and the caenogenetic ones? Simply by the method of comparison, that is, by von Baer's method; only, von Baer said 'homologous' instead of 'palingenetic', 'analogous' instead of 'caenogenetic'. Was anything else possible? How could any one hope to read the past by studying what is happening to the embryos of to-day? If such a thing were possible we ought, from the study of modern philology, to be able to guess at the contents of the lost manuscripts of the ancient world; archives would lose their purpose if history could be reconstructed from the study of modern times. Biologists were led into error by the impassioned way in which Haeckel affirmed the truth of his theory. They did not notice how impossible his inferences were; they set to work to collect facts which were to prove the validity of his biogenetic law, to see how far the law was capable of application to other fields, and to use the theory in support of Darwinism.[1]

The Gastraea Theory.

Ten years after the appearance of the *Origin of Species* Huxley published a monograph on the Medusae, in which he pointed out that their bodies are two-layered, and that a similar two-layered stage is invariably found in the embryos of vertebrate animals during the early stages of embryonic development. In both cases the layers stand 'in the same physiological relationship' to each other. In the Medusae the outer layer forms the epidermis and the muscle, the inner the digestive tract and the reproductive organs. According to von Baer, similar organs arise from the corresponding layers of the vertebrate embryo.

When Huxley's book appeared many other forms with two-layered bodies were known; most marine larvae went through such two-layered stages; from these the coelen-

[1] An historical review and criticism of the fundamental law of biogenesis is given by T. H. Morgan in his *Evolution and Adaptation*, New York, 1903, p. 60 sq.; also by Hurst in his 'Biological Theories', iii.: 'The Recapitulation Theory,' *Nat. Sc.*, ii, 1893.

terata, echinoderms, worms and molluscs develop. On these facts Haeckel built up his gastraea theory.

From the frequent occurrence of the two-layered gastrula stage he concluded that all many-celled animals pass through this stage in the course of their embryonic development. The gastrula may be pictured as like a rubber ball with one side pushed in. He concluded that the first stable form of the multicellular animal must have been like a gastrula. He called this hypothetical ancestor of all many-celled animals a gastraea.[1]

All multi-cellular animals, then, are descended from the 'Gastraea'. These descendants developed along two lines; the one form, 'Protascus,' was the starting-point of the coelenterata; the other was 'Prothelmis', from which the worms and all higher animals have evolved. Protascus was a free-swimming form, and retained, as did the coelenterata, its descendants, the radial symmetry of the gastrula. Prothelmis, on the other hand, crept over the floor of the ocean; its descendants became bilaterally symmetrical.

We may quote Haeckel, and give the following phylogenetic series to illustrate the further evolution of the two forms—Protascus and Prothelmis.

1. Protozoa—single-celled animals to whom the gastraea theory does not apply.
2. Metazoa—the many-celled animals.

2. (*a*) Coelenterata, in which the body remains two-layered throughout life. These comprise the lower forms, in which there is never any trace of a third layer; (here are included the simple sponges, hydroid polyps, and simple jelly-fish); and higher forms, in which so-called 'mesoderm' cells begin to appear between the two primitive layers; these cells never form a complete layer. Here are included the corals, the higher jelly-fish, and flatworms.

2. (*b*) Coelomata, in which there is, between the outer and inner layer, a space formed between a double middle

[1] *Die gastraea theorie*, 1874.

layer; this space is the coelom. To this group all the higher animals belong.

Haeckel's gastraea theory was soon attacked. Claus, a well-known Viennese zoologist, criticized it in the very year of its publication. He said, firstly, that, although almost all animals *do* pass through a gastraea stage in their development, this gastraea is not produced in the same way in all these animals, hence it is absurd to suppose that it represents some common ancestral type of organization. Further, there is absolutely no palaeontological evidence in support of the suggestion that *Protascus* and *Prothelmis* ever existed; the oldest-known animals are not radially symmetrical, as they should be according to this theory, but bilaterally symmetrical.

Many agreed with the first of these criticisms. Nevertheless the theory was generally accepted, and for a time it dominated embryology. Each objection was explained by the assumption that adaptations to new environmental conditions had led to deviations from the typical gastrula form.

The popular idea of the method of the scientist is that he assembles a series of definite facts, upon which he founds his theory. We see that this is not always the case. It is not true that the facts which told against the gastraea theory were unknown when the theory was propounded; or that the theory was gradually discredited as the facts which contradicted it were gradually accumulated, until it had finally to be abandoned. Everything important that has ever been cited against the theory was known when the theory was first put forward; nevertheless it was widely accepted. To-day some still accept it; others do not. Those who have abandoned it have not done so because the facts contradict it, but because their attention has been diverted into new channels by the modern inquiry into the phenomena of regeneration.

The facts of regeneration are difficult to reconcile with the Gastraea theory. Some investigators, it is true, have endeavoured to show that, when an organism regenerates

a lost limb, it does so by processes similar to those by which that limb was developed from the egg-cell. But regeneration is often a very different matter from embryonic development—the processes involved are not the same, and yet the two eventually lead to the same result.

It is possible to produce artificial mutilations without paying the least regard to the 'fundamental biogenetic law'. How, then, can this be as fundamental as Haeckel believed it to be?

The Monera.

In 1861, during the interminable controversy as to the significance of the cell theory, Max Schultze, a German zoologist, propounded his definition of the cell: 'a mass of protoplasm provided with a nucleus.' We might have expected that investigators would now devote themselves to the task of trying to discover why bodies are composed of cells; why every cell must have a nucleus; why the cell can only increase by division, and so on. But the theory of evolution gave a different direction to the study of the cell. Darwin's followers held that questions concerning the ultimate nature of living phenomena savoured of metaphysics, although equally fundamental questions were being studied by the physicists. Science, they held, is only concerned with the collection of facts concerning structure, with the sorting of types into evolutionary series, and with devising structures which would fill in the gaps in such a series.

It was in this spirit that Haeckel studied the cell. For him the cell, with its protoplasm and nucleus, was an advanced structure. He set out to imagine something still simpler, and distinguished between cells and *cytodes*, which consist of a substance (Plasson), in which nucleus and protoplasm are as yet undifferentiated, while he gave the name *coenocytes* to masses of protoplasm containing many nuclei. Organisms made up of cytodes were called *Moneras* by Haeckel. He asserted that large numbers of them exist and that they represent the first step in the pro-

cess by which non-living matter becomes endowed with life (*Monographie der Moneren*, 1868; *Studien über Moneren und andere Protisten*, Leipzig, 1870).

Haeckel believed that monera 'crystallize' from non-living matter. These monera, together with the simplest protozoa, form, according to Haeckel, the boundary between the plant and the animal kingdoms.

It looked as if this theory of the monera was to receive striking confirmation. When the first Atlantic cable was laid there was found on the ocean floor a gelatinous slime which, according to Huxley, consisted of small particles of transparent jelly, mixed with little calcareous granules. Huxley thought the jelly to be the protoplasm of some primitive organism, which he named *Bathybius Haeckelii*, and placed among the monera. During the voyage of the *Challenger* (1879) it was, however, shown that the *Bathybius* is but an inorganic jelly. Huxley hastened to repudiate his discovery while Haeckel consoled himself for a time with a similar discovery in the neighbourhood of Greenland.

A similar fate overtook another hypothetical ancestor of the animal kingdom—the so-called *Eozoon*. The oldest Canadian gneiss contains a certain marble in which are scattered granules, strands and bands of serpentine and other silicates. The serpentine lamellae are often wavy as if formed of cells, and the spaces around them in the marble are also penetrated by this serpentine. Some thought this the remains of an extremely primitive organism—the shell represented by the marble, the cast of its body by the serpentine. The belief in its organic origin was gradually dissipated, and now no one holds this view.

There were other factors at work which caused the belief in the monera to be gradually abandoned. When Haeckel propounded his theory the cell-nucleus was believed to be nothing but a mass of denser protoplasm. Towards the end of the century, however, histologists began to study the minute structure of the nucleus and its very striking living processes, and the protoplasm

came to be regarded more and more as an undifferentiated covering to the nucleus. The monera then became an anachronism; and though it was referred to in the text-books until a few years ago, this was merely due to inertia on the part of writers.

Haeckel's idea of a middle kingdom, the *Protista*, intermediate between plants and animals, was also gradually discarded. It went the way of earlier theories of a similar kind. In the eighteenth century, and indeed back to Aristotle, the belief had been very generally held that beings exist which are half-plants, half-animals. These were called *Zoophytes* (plant animals). Lamarck's pupil, Bory de St. Vincent, was a strong supporter of this idea.

Haeckel's Influence.

Many other theories streamed from Haeckel's fertile brain—of spontaneous generation, of the origin of speech and of Man, and so on. Here we will add a short note on *Monism*—the theory which Haeckel put forward in opposition to the teaching of the Church. He added nothing to what Strauss had already said, and he continually quotes the work of Strauss. There is no duality of soul and body, living and non-living matter. The only thing that exists is matter, and this is composed of atoms. There is no personal immortality, although matter and force are both indestructible. The God of Christianity is merely a personification of human attributes. Haeckel is full of hope that 'ancient superstitions' will be swept away by science, and that their place will be taken by the theory of evolution and its servant monism. For monism teaches that the world was gradually evolved out of some primeval substance (Kant and Laplace), that life arose from the non-living according to mechanical laws, and that everything that exists, even atoms, have souls. Man is merely the most perfect animal. He owes his dominant position to the fact that, in his body is a combination of characters which elsewhere only occur singly (e.g. a larynx, brain, limbs, and the upright position). Traces

of religious feeling, of a moral sense, of powers of judgement are exhibited by certain animals.

Haeckel's popularity led his followers to regard the Church with complete indifference, and this led, in its turn, to passionate opposition. His attack on the Church is now out of date, as is also the Church's criticism of his teaching. Those interested in this controversy will find many more original thinkers taking part in it than Haeckel.

Haeckel wrote the first history of the theory of evolution. Many have followed him in this as in all his other activities. A writer who was anxious to show how great was the influence of Aristotle once said that all those who went before were his 'forerunners', while all those who came after were his imitators. Haeckel's opinion of Darwin was equally high. Hence, one of the chief occupations of those who essayed to write histories of biology became the discovering of Darwin's forerunners.

Haeckel exerted a very great influence on his contemporaries. Neither Darwin nor Huxley alone would have succeeded in making the evolutionary theory the world-power that it became; for Darwin was no controversialist, while Huxley was not sufficiently dogmatic to influence the masses. Haeckel possessed both these qualities in a very high degree.

First it was necessary to break the power of the specialists—for these, like any other conservative group, believed themselves to be the *beati possidentes* of all truth. They did not try to understand new and strange theories. Only when he had won the approbation of the masses by his popular writings did they admit, under protest, that Haeckel was a leader of biological thought.

His influence in informed circles was partly due to his own absolute conviction, but even more to the fact that he did not demand from biologists any complete change of view. Under his leadership a morphologist could remain a morphologist, an embryologist be still an embryologist, the systematist could still continue to weave his systems.

None of these branches of science was condemned by the new philosophy; none was dislodged. The only demand made by Haeckel was that the word 'evolutionary' should be affixed to each of them. The religious difficulties of the Radicals were settled by all sorts of compromises, and so their path was smoothed.

For nearly forty years Haeckel was the leading figure in biological science, the acknowledged or unacknowledged head, always ready to fight for his convictions.

It is hardly possible to count the number of those who, when his fame was at its height, hitched themselves to his triumphal wagon. He had philosophers among his followers, especially in Germany (A. Lang, G. Fechner, E. Hartmann), as well as sociologists, students of ethics and of language, and above all, biologists. From 1870 onwards morphology has dealt solely with the questions that Haeckel propounded, and the embryologists have been completely under the spell of his fundamental law of biogenesis. Darwin, Huxley, Gegenbaur, Ray Lankester, F. M. Balfour, Wiedersheim, Forel, &c., were all his faithful followers. Until recently Haeckel's pupils were the leaders of German science—Oscar Hertwig in Berlin; W. Roux, who founded evolutionary mechanics, and who admitted that his theories were evolved from those of Haeckel—and it is obvious that they are merely an adaptation of these; Verworn, the Jena physiologist, who not many years ago won a great reputation by applying these theories to physiology.

To-day Haeckel's influence has waned, and he is declared to be unscientific. How often do we hear Haeckel disparaged while Darwin is praised for his care and caution? Who could guess, without delving into forgotten records, that Darwin accepted all Haeckel's theories—indeed, did more than this. When Haeckel's most important book, *Natürliche Schöpfungsgeschichte*, was published, Darwin said:

'If this work had appeared before my essay had been written I should probably never have completed it. Almost all the con-

clusions at which I have arrived I find confirmed by this naturalist, whose knowledge on many points is much fuller than mine' (*Descent of Man*).

When Darwin is praised for his modesty, in opposition to Haeckel's bombast, how many remember the explanation he gave of the process of menstruation, for example? He said that it dates from the time when the ancestors of the human race lived in the sea, where they were at the mercy of the waves, which depend in their turn on the tides, and so on the 'moon'. And did not Darwin also publish a genealogical tree for man? Haeckel is condemned because he wrote about religion and philosophy without real knowledge. How much did Darwin understand of the views of the theologians and philosophers?

XIII

SPONTANEOUS GENERATION

PHILOSOPHERS of the early Christian era delighted in contrasting God's omnipotence with man's impotence. 'We are mere flesh, a mere breath, and we depart never to return,' said St. Augustine, echoing the 90th Psalm. Such, too, is the teaching of modern science. Man is only a grain of dust, a moment, a nothing-at-all in a boundless universe.

Nevertheless, medieval ideas were not at all akin to those of our own times. In those days, though Man was believed to be as nothing when compared with the creative idea, with an all-powerful God, he was regarded as the lord of the material world, the ruler of the earth and of all that is therein. Animals and plants were created solely on his behalf. In our times we strive to 'explain' material phenomena, and have lost the overwhelming conviction of an Almighty God. We make our estimates of the age of the earth; we are thrilled with its antiquity; we are rendered dizzy by the billions of miles in which we measure the extent of the universe. We recognize the immensity of space, and it is in this way that we become conscious of our own insignificance.

The whole trend of modern science leads us to the realization of our weakness. Copernicus, Galileo, and Kepler robbed our earth of its proud dominion, and made it a mere hanger-on of the infinitely greater sun. Later she sank still further, becoming a mere grain of sand among a myriad stars—a grain scarcely noticeable from those vast spaces which are about the stars.

Geology has disclosed that Man's time on the earth is merely a short episode in the countless eons of the world's history. Every new discovery extends the boundaries of the knowable universe and decreases the significance of Man and that minor activity we call Life.

There are illimitable events and phenomena quite outside every form of life. Only the thin crust of the earth is habitable, and its tremendous interior is not available to any living thing. Only by a stretch of imagination do we dare to dream that any of the planets are inhabited, and there is certainly no life in the glowing bodies of the sun and the fixed stars. Life is only possible between extremely narrow physical and chemical limits, and the slightest disturbance can destroy it completely.

Belief in spontaneous generation, in the origin of life from non-living matter, is as old as is conscious thought about Nature. We read it in the myths that man arose from stone, gods from sea-foam. Aristotle believed and taught that frogs may arise from slime. The alchemists were always hoping to be able to create man from the mixtures in their phials. The idea once held that fossils merely represent Nature's unsuccessful attempts to produce life is an aspect of this belief. All these ideas expressed the conviction that life is everywhere, and that if the right means be used this life may be awakened.

A belief in spontaneous generation was still current even in the early nineteenth century. Johannes Müller, in his *Physiology* (1837), mentions several writers who believed in it and quotes various arguments in its favour. He rejects the idea on the balance of evidence, but without any overwhelming conviction; in particular he finds it difficult to imagine how life can otherwise have first appeared.

The literature of those times is full of references to 'Priestley's matter'—the thin film of microscopic green algae which is liable to form on water. Some believed that this material arose out of the water itself, and that from it the higher plants and animals were derived. Thus in 1821 a writer describes how he *saw* minute crustacea (*Cypris* and *Daphnia*) arise from algae; and how from their dead bodies algae arose once more, to give rise in their turn to similar crustacea. Purkinje believed in spontaneous generation, and said he had observed it in the fungi and elsewhere.

Not every investigator believed in the origin of life from non-living matter, but even the sceptics had very few facts to argue from—their appeal was chiefly to general considerations. Ehrenberg led the unbelievers; using a poor microscope, he observed the living forms in a drop of water; he noted that the wheel Rotifers have various internal organs. He failed to distinguish these from Infusoria, and noted that the latter also showed some internal organization (nucleus and vacuoles), though these he could only dimly see. He therefore concluded that the Infusoria have a stomach, sexual organs, &c., and from this he inferred that even the lowliest organisms are so complicated in structure that it is impossible to believe they have crystallized out from non-living matter. In those days the method of propagation of many lowly forms of life was unknown, and it was thus easier to believe in spontaneous generation. Ehrenberg, however, saw the Infusoria reproduce by division, and this increased his mistrust.

The question continued to be discussed, though without conclusive result. But at last in 1862, driven to it by the definite assertions of Pouchet, the French Academy offered a prize for a new experimental solution of the whole question. Pouchet had asserted that the eggs of various forms of life arise spontaneously in turbid water, and develop there as well as in the natural body if air, warmth, and electricity are given to the decaying mass (1859). Pasteur received the prize.

Pasteur first examined the air itself. He drove air through a filter of cotton-wool. This caught all the floating solid matter. In this filtrate he found microscopically many of the lower forms of life and their spores. Further, he submitted a mixture of sugar solution and yeast to prolonged boiling, and let it cool in air which had been strongly heated. The sugar-containing vessel was then sealed. In the fluid nothing living developed, even when he passed through it more heated air. If ordinary unheated air, on the other hand, had access to the solution, living organisms developed in it at once.

So Pasteur solved the problem—at least in the form propounded by Pouchet; but the question continued to be discussed by the Academy. Pouchet's supporters brought it to the notice of the newspapers, who took Pouchet's side! Interest was, however, subsiding, when it was reawakened by the English physician Bastian who, using Pouchet's methods, arrived at similar conclusions (1872). He introduced a theory of infectious disease which was based on these observations. Bacteria do not infect the body from the outside—they develop within it. These views were challenged by J. J. Lister, afterwards Lord Lister, who originated antiseptic methods in surgery. Bastian, however, continued his work, and in 1903 he published a large book in support of his earlier views. The book passed almost unnoticed. From time to time rumours again arise that this, that, or the other experimentor has succeeded in producing bacteria, or other simple forms of life, from dead matter. Such rumours are always received with mistrust. The mistrust is justified, for such experiments do not attempt to throw any new and independent light on the problem of the nature and origin of life. They always begin with the assumption that, somehow or the other, life must have arisen out of the non-living.

The problem has been attacked more recently from another point of view. Life, it has been assumed, consists in some peculiar activation of matter, and so the attempt has been made to imitate some, at least, of the activities generally associated with living matter.

Quincke, a physicist, suggested that an amoeba moves through water because the molecular tensions between the surface of its body and the water particles are altered at certain points; the change leads to a movement in the direction of the smallest tension. The trend of this argument becomes clear if we remember the streaming movements that occur in water when alcohol is poured into it. The movements that occur between the amoeba and the water were supposed to be of this order. By choosing the

right combination of fluids Quincke succeeded in imitating amoeboid movement.

Interest in these experiments became more general when Bütschli propounded the theory (1892) that living matter consists essentially of two substances which, when mixed with one another, form a 'foam'. Bütschli attempted to demonstrate this structure in various living cells and to show how the living activities of the cell may result from it; he also tried to make artificial foams which should behave to some extent like living matter. He prepared a substance by soaking benzol (or xylol) in a soap solution. He asserted that this was very much like the protoplasm of certain cells. Others improved upon this method of making 'artificial protoplasm'. It was found that a drop of a mixture of very finely powdered sugar or common salt with inspissated olive oil, exhibits a structure much like that of protoplasm, and even moves almost like an amoeba.

In recent years investigators have turned their attention from such experiments to the finding of analogies between the behaviour of certain lifeless objects and certain living processes. Rhumbler endeavoured to construct mechanical models which would imitate the behaviour of the living cell during division. Lehmann, the crystallographer, described a new group of crystals, and he pointed out certain analogies between the movements of such crystals and the simpler movements of living matter. Some workers would have us believe that there is a striking analogy between the phenomena of regeneration, exhibited by certain organisms, and the power which some crystals have of regaining their perfect form, if a small fragment is immersed in a supersaturated solution.

More recently still, it has been suggested that radium, —that 'philosopher's stone' of modern experimental science—may have been able to bring about the spontaneous production of life.

A few biologists abandoned the attempt to discover the origin of life, and attacked the problem from the opposite pole. Life, they suggested, must always have existed, and

lifeless matter have been produced by it. This led W. Preyer (1877) and certain other thinkers to very fanciful lengths.

There were others who thought that life had been transferred to our planet from other worlds, carried thither by meteors; that it is the Wandering Jew of the Universe, journeying from one planet to another, to remain for a time, to develop, and then, as the planet cools, to disappear once more, only to develop again on a new planet.

Scientists have not been wanting who thought that they had discovered known forms of life—sponges, corals, crinoids, and the rest—existing as fossils in meteorites!

XIV

ANTHROPOLOGY

§ 1. *Views of the Origin of Man.*

IN the early ninteenth century there were few scientists who still believed that Man, fashioned in clay, had come direct from the hands of his Maker. The conviction had spread that there was more than one Adam. Philosophical and political discussions concerning the equality of man had exerted an influence on science. The question of the freeing of the American negro slaves led not only to the war of North versus South—it also divided anthropologists into two camps, the one believing in the equality of white and black races, the other stoutly denying it. In America, in particular, the view that the negro is as far removed from the Caucasian race as he is from the chimpanzee was a very popular one. He is descended from a different Adam. This was the view of Agassiz. Other writers suggested that there must have been at least 180 Adams, as many progenitors as there are subdivisions of the human race!

These ideas and the theories of Darwin were poles asunder. Agassiz suggested that there had been many more and more perfect Adams—from the ancestor of the modern chimpanzee to the founder of the whole white race of mankind. He nevertheless believed that each of these suggested ancestors was an independent creation; each represented a separate thought in the Mind of the Creator. The chimpanzee ancestor embodied an animal design, the white Adam the idea of an intelligent being.

Darwin held that the chimpanzee and Man are fundamentally alike, but Man has become more highly evolved, has a larger brain, and commands a wider experience. Moreover, Darwin did not believe in the existence of any Adam, in any beginning; only in a history which had lasted for millions of years, which had not yet reached

its climax, but which was going forward to a higher future —a future as yet all unknown. The path had been prepared for this view in many ways.

§ 2. *Palaeontological Evidence.*

Cuvier believed that Man has only existed during the most modern geological epoch, and that he has always inhabited the parts of the world which he inhabits today. He brought much learning to prove that Man is not older than is claimed by the Bible. He defended the assertion that there were no fossil men in the face of those cases where fossil human remains were said to have been found. After his death such finds increased in number both in France and in other countries. For this a large share of credit must be given to the French investigator, Boucher de Perthes. From 1839 onwards he was a diligent seeker for traces of prehistoric man. For long his work was ignored, but at length he received from anthropologists the recognition that was his due.

Similar investigations were pursued in Sweden. In 1863 Charles Lyell, in his *Geological Evidences of the Antiquity of Man*, gave a summary of these scattered references to prehistoric man, and so was led for the second time into opposition to Cuvier. The book was not very well received in England; it was said to be a mere compilation. Lyell's personal prestige was, however, great, and the book made itself felt in Germany, where investigators turned their attention to the most recent rocks. Lyell held that there had never been a Flood—a general catastrophe which had engulfed the whole world. He pointed out that, in the fables of most peoples, inhabiting widely separated portions of the globe, there is a story of a flood. We find it among the Chinese, the South American Indians, the Egyptians, &c.; anywhere, where there are great rivers and seas subject to those local floods which were the foundation of such tales. The geological idea of the Diluvium was now given, for the first time, a definite form; it is the consequence of the erosive action

of wind, water, and glacier—such erosion going on for thousands of years.

Lyell had arrived at the knowledge that Europe had experienced great extremes of cold at an early date. Later geologists proved that there had been several such epochs in our latitudes, between three and six at least, during the period in question. During the so-called tertiary period, the climate had been so mild that sub-tropical plants and animals flourished in France, while in Greenland, where to-day only the hardiest of plants can maintain a miserable existence, palms once grew abundantly. Then followed many centuries of extreme cold, when glaciers stretched southwards into the plains of France and of Bavaria, when practically the whole of England, the whole of North Germany from the mouth of the Rhine to the northern boundaries of Bohemia, and the greater part of Russia, lay under a covering of ice. Warmer times followed; the glaciers receded until all that was left were the ice-caps on the tops of high mountains. Then they began to creep down into the valleys once more. As the second ice age spread southwards, animals and plants that needed warmth either moved southwards too or died out and were replaced by new forms from the north. On the cold plains which bordered on the glaciers lived reindeer, mammoths, and rhinoceros, all clothed with a thick coating of hair, together with bears, hyenas, lions, and deer. These did not belong to the species which exist to-day.

This is the time that gives us our first distinct traces of the existence of man; there are his coarse stone tools, his drawings of the bones of animals long extinct; here and there, though not often, we find human bones. Most of these facts were known to Lyell. In later years French investigators discovered many caves which contained the traces—in the form of his tools—of primitive man; they found many such caves both in France and in Spain. Very soon they had worked out criteria for distinguishing between various periods in the evolution of pre-historic man; these criteria were derived from an examination of his

stone implements. The periods in question were the so-called Palaeolithic and Neolithic ages, the age of Bronze and the age of Iron; recently these periods have been further subdivided.

Some French and Belgian anthropologists believe that they can discern traces of even more primitive tools—tools used by men of the tertiary epoch, that is, by men who were living in France before the Ice Age, during the warm period referred to above. Others think that these stones, the so-called 'eoliths', are not the work of man, but that they have been heaped up in certain areas by natural means, and hence they do not believe in tertiary men.

It is quite certain that men were alive during the Ice Age, and that they were contemporary with animals which have long been extinct; but whether there have been men in Europe since the beginning of that epoch, or whether they only appeared during its course, is still a subject of discussion.

Ice-age man lived on the edges of the glaciers, together with mammoths, rhinoceros, and other extinct creatures. He probably clothed himself in skins and hunted wild animals. He may have driven them into some pit or abyss and then have collected their dead bodies; he also killed his victims with stone weapons. He lived in caves or in tents, and he had discovered fire. He had developed a certain artistic sense; he used coloured earths to paint pictures of animals on the walls of his dwelling, and he pricked out the contours of mammoths, of deer, and even of men, on the bones and pieces of horn which served him as weapons.

We do not know where was his home before he came to Europe, nor what became of him later; whether he died out, or whether his descendants lived on as the most ancient people into Palaeolithic and Bronze Ages.

§ 3. *Anatomical Evidence.*

With very few exceptions, our study of prehistoric man does not take us back across the threshold of the human.

The oldest known men were already of the human type, both in appearance and habits. They are further removed from apes than they are from modern man. The science of comparative anatomy has seemed so important that the philosophers of evolution have devoted most of their attention to anatomical considerations, and have attached very little importance to the historical facts.

The aim has always been to show that man, in his bodily structure, is not very far from the animal. Since the mentality was regarded merely as the result of certain nervous structures, it is obvious that mental differences would be looked upon as of minor importance. This likeness of man to the animal creation, because of the importance it assumed as a definite 'proof' of the theory of evolution, became a favourite subject with scientists in the second half of the nineteenth century, and these discussions roused the fury of the anti-evolutionary party.

Yet, before that time, the likeness had been accepted as a matter of course. It had been observed by Aristotle. Ennius had already said *Simia quam similis, turpissima bestia, nobis*! Galen studied the monkey to understand human anatomy. So great was the conviction that the two are absolutely similar that Vesalius introduced a reform by bringing proof that Galen was mistaken, and that the monkey is not anatomically so very close to man.

It is very instructive to examine illustrations of monkeys published in the eighteenth century, at a time when comparative anatomy was already an established science, and when monkeys were well known. In these illustrations they look just like hairy men, have intelligent faces, stand on their hind-legs, and carry a stick or a flower in their hand. Such pictures are to be seen in Buffon's works, and religious sensibilities were not affronted; the resemblance of man to the monkeys was accepted as obvious. Buffon defines an anthropoid ape as 'an animal without a tail, with a flattened face, with teeth, hands, fingers, and nails like those of man. It walks on two legs. This

definition excludes every tailed animal, every animal-faced creature, every animal with curved or pointed claws, all those who walk on four legs rather than on two.'

Linnaeus placed man in the same order as the monkeys without encountering opposition. Lord Monboddo discussed the question of the origin of man from monkeys. De la Mettrie hoped that one day we should succeed in teaching monkeys to speak and to behave! Kant's anthropology ends on a similar note. The morphologists of the early nineteenth century also discussed this question of the similarity between man and the animal creation.

Meckel published a detailed description of certain human monstrosities (1862). He used his hypothesis that man during his development from the egg passes through the lower and higher animal forms to explain the resemblance of these monstrosities to animals. This even explains why human monstrosities have occasionally been born with the heart of an insect, a reptile or a fish. Blumenbach described another group of monstrosities, in which he thought the human embryo resembled a frog. He, too, believed that such aberrations were to be ascribed to disturbances during development. Geoffrey extended his inquiry into 'unity of plan', and applied the idea to human structure. He described a series of human abnormalities to prove that parts of the human body are identical with corresponding parts of the animal body.

Nobody found such theories startling, for no one regarded mere bones as the final criterion. What did it signify if man possessed all the structures which are found in the animal body, and exhibited no single one that was peculiar to himself? All that mattered was the harmony, the unity of those structures, the idea which they made manifest. And so they laid stress upon man's upright gait, upon the structure of his hand and of his foot, upon his intellect and his morality—upon the 'ideal' in human life.

We may quote a passage from Buffon to show how, in

his day, when men were beginning to abandon idealism, but had not yet accepted materialism, they gave an ideal interpretation of the fact that men very closely resemble monkeys. Buffon devotes many pages to discussing similarities of men and monkeys. He shows that, if we compare the monkey with a primitive human type, instead of with civilized man, this similarity merges into an almost complete identity.

'We see, from our description of the orang, that, if we consider structure only, we might regard it as the highest animal, or, with almost equal justification, as the lowest man. For, not taking the soul into account, he lacks nothing that we possess; and in regard to bodily structure he is certainly nearer to man than to those other animals whom we also call by the name of monkey. If we consider structure only, we might quite well regard the race of monkeys as a variety of the human. The Almighty did not choose a new mould upon which to fashion man; He made him after the model from which He made the animals. Men and animals alike embody one great design. But into this material, monkey-like body He breathed His divine spirit.'

It is not difficult to find traces of Descartes' philosophy in this—a philosophy which regarded the soul as an addition to the body, as something which could be separated from it. That philosophy considers the soul as all-important. But, directly the materialistic aspects of this philosophy were emphasized, the belief in a soul lost all foundation—'ideas' became mere empty words, 'facts' became all-important. When this interpretation had become the common one, the doctrine of the relation between man and the animals assumed a very different aspect. 'Since he is so similar in body he *is* an animal' was now the assertion.

The difference in structure between thumb and big toe seemed, to the older writers, to prove that the hand of man was always predestined to fulfil special functions. In the newer view this difference simply represented an adaptation to new functions. And so the German materialists—especially Vogt (1863)—asserted very emphatically

that there is no essential difference in structure between the human body and that of the monkey. Huxley gave further arguments in favour of this assertion. Richard Owen had already pointed out the similarity. He was an idealist, convinced of the importance of the human reason; this gave him a foundation for his belief that Man is fundamentally different from all animals. Now the new philosophy regarded the soul as merely a product or function of the brain. Thus Owen was driven to try to discover bodily attributes which differentiated men from the apes. He pointed out that, in Man, one portion of the brain (*Pes Hippocampi Minor*) is much more highly developed than in the monkey; that in him it assumes a totally different form.[1] On this anatomical ground he placed Man in a separate division of the animal kingdom, the *Archencephala*.

Huxley was already prejudiced against Owen. He took advantage of the opportunity to declare his opposition publicly. He asserted that there is no essential difference between the apes and Man.

'The structural differences between Man and Man-like apes certainly justify our regarding him as constituting a family apart from them; though, inasmuch as he differs less from them than they do from other families of the same order, there can be no justification for placing him in a distinct order. . . . All the abundant and trustworthy evidence which we now possess leads to the conviction that so far from the posterior lobe, the posterior cornu, and the hippocampus minor being structures peculiar to and characteristic of Man, it is precisely those structures which are the most marked cerebral characters common to Man with the apes.

'The structural differences which separate Man from the gorilla and the chimpanzee are not so great as those which separate the gorilla from the lower apes.'[2]

These words of Huxley raised a storm of controversy. So much were the times changed! A hundred years earlier

[1] R. Owen, 'On the Characters, Principles of Division, and Primary Groups of the Class Mammalia,' *Proc. Linn. Society*, 1857.

[2] Th. H. Huxley, *Evidences of Man's Place in Nature*, 1863.

men of science had taught that man only differs from the ape in the structure of one organ; this organ was not the *Pes Hippocampi*, however, it was the *Intermaxillary bone*. In 1786 Goethe had asserted that man possesses this bone, but no one considered that this fact altered the place of man in Nature; all that disturbed Goethe was that people did not pay enough attention to his discovery. Now Owen, the follower of Goethe, denied this principle while the opponents of idealism were defending it. They did so, convinced that thereby they were founding a new philosophy. We are reminded of the sigh that escaped from Goethe during the discussion of the intermaxillary bone:

'I can well believe that the man who is an academic by profession would swear away all his five senses; for he is not concerned with the living idea—he only wants to know what other men have said about it.'

Darwin's Views.

In the *Origin of Species* Darwin had indicated that his theory might also apply to Man; in 1871 he set forth his views in the *Descent of Man*. Various motives induced him to take this step, though Lyell and Wallace, his supporters in the controversy, had objected to this extension of the evolutionary theory. The book created another sensation, though it is not as great a work as the *Origin of Species*. The earlier work contains many of Darwin's *own* observations, while in the *Descent of Man* he discusses anthropology, sociology, medicine and philosophy without having any very exact knowledge of any of these subjects. It is not very surprising, therefore, that his examples are not always apt, his arguments not always scientific, and his conclusions not always sound.

Darwin taught that Man has been gradually evolved from some lower form of life; that he is akin to the animal both in body and in mind; that he has many rudimentary organs which are reminiscent of his animal structure. Like the animals, man undergoes variation; these variations

are inherited. He is also subjected to the 'struggle for existence'.

Darwin's psychological explanations form the best part of the book, for here, more than in other parts of it, he is describing his own observations. He believes that Man is only a glorified animal, even on the spiritual plane. He admits that Man stands well above the animals, but there are great differences between the mentalities of animals—between, for example, that of a dog and that of the simplest fish. Man shares his sense organs with the animals; hence he must have the same primitive sensations. Many of his instincts, too, he shares with them—the desire to live and to increase his kind; mother love; the child's instinct to suck at the breast, &c. Looking at the reverse side of this picture, the animal feels joy, pain, happiness, misery; the young of dogs, cats, and sheep like to play, as do human children. Animals can be bad-tempered and ambitious; dogs have also a certain sense of shame and a certain modesty. Monkeys are discomfited when men laugh at them. Dogs possess imitativeness in a high degree; they have concentration, memory, phantasy, understanding, and the ability to learn the use of tools. They even have a form of speech. Darwin's dog, when he barked at a sunshade which was moved by the wind, showed the beginnings of religious feeling, and he regarded his master as a god. He was also subject to remorse!

This was the first attempt to note in what ways Man and the animals resemble each other—an attempt unhindered by scruples or mental reservations—taking simply evidence derived from first-hand observation.

Darwin's discussion of the origin of Man was extremely inadequate. He constructed a genealogical table which began with the Tunicates and Amphioxus, and passed on through the Reptiles, Marsupials, and Monkeys. This only differs from Haeckel's in that it is expressed with greater caution. He describes how Man has reached his present position as the result of natural and of sexual selection.

Darwin attached great weight to sexual selection and attributed the origin of speech to it, as also the ability to sing, the loss of hair, the differentiation of mankind into divers races, and so on.

Many treatises have been written since the days of Darwin dealing with the resemblances between men and monkeys, but no very important facts have been added to the discussion. We may, therefore, at this point, briefly summarize the more important features which are characteristic of the human body, and point out the views of anatomists concerning them. The most striking human characteristics are: a large brain and the head shape which goes with this; a chin; fleshy lips; a nose which projects from the face; the feminine breast; the soles of the feet; the non-hairy body; the upright position; the form of the hand with fully opposable thumb; a continuous row of teeth (in the monkeys there are spaces between the teeth) &c. Anatomists assert that some of these characters are of minor importance, e. g. the fleshy lips; that others occur in certain animals, e. g. some monkeys have a projecting nose; that others, again, have arisen because of man's peculiar mode of life, e. g. the characteristic soles of the feet, the upright position, the large brain. They further point out that certain organs are vestigial in man and better developed in animals—for example, rudimentary muscles for moving the skin, ear-muscles, vestigial tail vertebrae, and so on. They attach importance to certain atavisms which occur occasionally: men with more than thirty-two teeth, with a rudimentary tail, a hair-covered body, and similar abnormalities.

More recently there was an attempt to prove that human blood is chemically very much more akin to that of the anthropoid apes than to that of the lower monkeys;[1] further, that the embryo *in utero* is attached by a single

[1] R. Wiedersheim, *Der Bau des Menschen als Zeugnis für seine Vergangenheit*, Leipzig, 1887. In this book he gives a list of rudimentary structures found in animals which show some resemblance to definite human characteristics. Grünbaum, in *The Lancet* of 1902, discusses the blood-relationship between men and monkeys.

placenta in both man and the higher apes, while in the old-world monkeys it is attached by two placentae. But the subject no longer claims attention. We have grown used to having the similarities between men and monkeys pointed out to us, and the arguments have lost their original freshness.

The Missing Link.

The evolutionists were always hoping that something intermediate between man and the monkey would be discovered. At one time they looked for this link among primitive races of mankind, at another among human fossil remains.

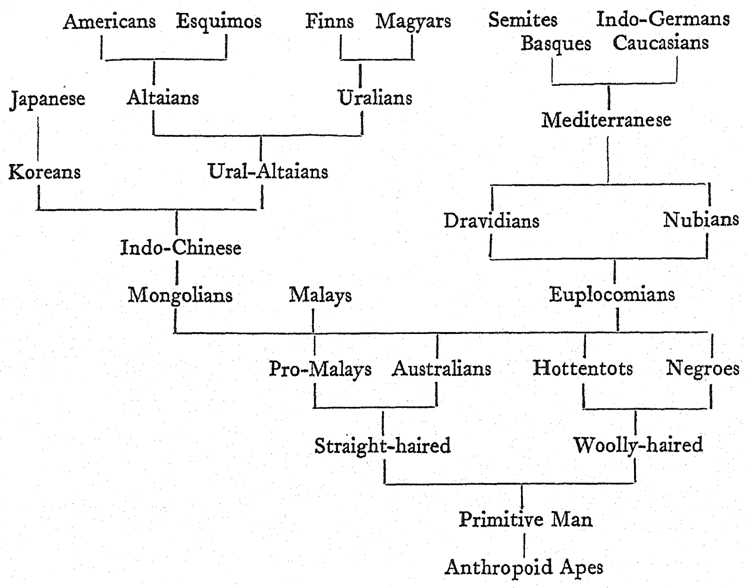
While little was known about them, uncivilized peoples were described by travellers as extremely brutalized. In the eighteenth century there was a very general belief in the existence of completely savage and bestial men. Even Linnaeus divided mankind into two classes—*Homo sapiens* and *Homo ferus*—and, according to his definition, the members of the latter class were four-footed, dumb, and hairy! Such ideas have been discarded—nevertheless this much is certain; that some races are on a lower plane than others, both anatomically and mentally. The aborigines of Australia may be cited as an example.

On this account most of the evolutionists who investigate human origins believe that these peoples represent the forerunners of 'intelligent' man, or that they are close relatives of those forerunners.

Haeckel's genealogical tree may be given as an example of this type of speculation.[1] Like all such trees, this has been criticized; other writers would express the relationships between the various peoples differently. Some (Schoetensack, Macnamara) think that the cradle of humanity was in the islands of Melanesia; Ameghino seeks it in South America, Klaatsch thinks it will be found in Europe. Kolmann suggested that the first men were

[1] I cite, in a simpler form, Haeckel's tree showing the pedigree of Man from the 5th edition of his *Natürl. Schöpfungsgeschichte.*

dwarfs, and that these gave rise to two dwarf races—a black race and a yellow one, who only gradually attained their present stature.



The affinity with monkeys is not universally admitted. Klaatsch, for example, suggested that Man had evolved from a marsupial; this marsupial forbear had first of all developed certain simian characters, and then it evolved into a very primitive human type. He thought that modern apes are a degenerate stock, representatives of abortive deviations from the direct line of human evolution.

This study of the comparative anatomy of living races was eclipsed by the interest aroused when fossil remains of prehistoric man were first discovered. Virchow was certain that the bones found were those of real men who had lived in a community. He found on these bones the traces of wounds that had healed, also the marks of disease, and he said they gave obvious evidence of human care; when more skulls were found, however, this contention was shown to be untenable.

In 1856 the so-called Neanderthal skull was discovered in a cave near Düsseldorf; this had a very low forehead and very pronounced frontal ridges. These discoveries made Virchow less certain of his position. Subsequently in 1901–2 Gorjanovic Kramberger discovered the broken remains of ten similar skulls at Krapina, in Croatia; these showed the same primitive Neanderthal characters—indeed, they are perhaps even more primitive.

In 1907 Dr. Schoetensack discovered a perfect lower jaw of the pre-Neanderthaloid type, in a cave near Heidelberg—*Homo Heidelbergensis*. This fragment probably dates from the second Interglacial period.

The Java ape-man—*Pithecanthropus erectus*—was discovered in 1891 by the Dutch observer Eugène Dubois; the remains consisted of two teeth, a part of a skull, and a left thigh bone.[1] Dubois and others described this creature as intermediate in structure between the ape and Man—hence the name; it seems to belong to the upper Pliocene or the lowermost Pleistocene period.

The remains of another fossil man were found in France, with characters apparently intermediate between those of Neanderthal man and Pithecanthropus erectus. This man must, however, have been partially civilized, as he was found in an artificial grave. More recently there has been the very important discovery of Rhodesian man.

There has been great progress in the study of physical anthropology since Darwin's time, for many new facts have been discovered. But the methods of this science are still the methods of the Darwinian school. In this respect it lags behind other branches of biology which have tried to strike out along new paths.

[1] Haeckel invented the name Pithecanthropus. Dubois thought that his discovery was a form intermediate between Man and the ape, and he would have placed it in a special family. Schwalbe submitted these bones, which Dubois had discovered, to an anatomical investigation. Voltz and Selenka affirm that Pithecanthropus represents a fairly advanced human type—a type living socially.

XV

HUMAN RACES

THE present inhabitants of the earth, especially those who are civilized, are linked up into societies, held together by ties of nationality, of language, territory, religion, custom, and history. Philosophers and politicians are not agreed as to which of these spiritual ties is the most important. The result of the view that man is only a higher animal, that his soul is the product of his body, has been that, during the latter half of the nineteenth century, special importance has been attached to the anthropological and biological aspects of racial problems.

Man is one species, with several varieties. There is no general agreement as to either the number or characteristic features of those varieties. J. Blumenbach (1752-1840), the founder of the science of physical anthropology, divided mankind into five races—Caucasian, Mongolian, Ethiopian, American, and Malayan. Modern anthropologists divide him into many more races, and link these up into groups. Thus E. Fischer classifies as follows:

I. European—Mediterranean—Asia Minor group, including the Nordic, Alpine, Mediterranean, and Dinaric stocks.
II. The African group. Pygmies, Bush-men and various other stocks scattered over Africa; Negroes.
III. The group inhabiting the Oceanic Islands. The Negritos, Malays, Dravidians.
IV. The group inhabiting Australia and the Southern Pacific Islands. Australians, Melanesians, Micronesians, and Polynesians.
V. The East, Central, and Northern Asiatic group. Japanese and other Mongolian stocks.
VI. The American group. Indians.
VII. The Arctic group. Esquimos.[1]

The European populations exhibit a mingling of the

[1] See 'Anthropologie' in E. Hinneberg's *Kultur der Gegenwart*, 1921.

characters belonging to several of the above groups; this was said to be due to crossing between the groups. Stimulated by Virchow, attempts were made in Germany, Austria, Belgium, and Switzerland to demonstrate this mixture of racial types among school children. The colours of hair, eyes, and skin were examined, and the examination gave the following results:

In Germany 31·8 per cent. were of the blonde type, 14·05 per cent. brunette,

In Austria 19·79 per cent. were of the blonde type, 23·17 per cent. brunette,

while the remainder of the population belonged to a mixed type. The fact that blondes were more numerous in Germany led Virchow to suggest that in the south there had been much admixture of the fair-haired Germanic type with the more southerly darker-haired races—with Italians, Slovenes, Wallachians, and Bohemians.

Virchow also compared skulls, and came to the following conclusions:

The Celts were dark and round-headed, the Germans and Slavs fair and long-headed. As we pass from North to South, across the Alps, the long-headed types become rarer, the round-heads more numerous. There has, however, been a great deal of crossing between the two types.

Most students of these racial problems have put forward similar theories, upon facts supplied by anthropologists. There has been a general tendency to devote a great deal of attention to the details of structure and to neglect psychological elements. The idea that races are held together by their history, religion, political views, and geographical conditions, &c., was gradually dropped; these theorists thought that race, i. e. physical characters, formed the real link.

Woltmann belonged to this school. He adopted Haeckel's view that the history of man is merely a fragment of the history of the organic world. He condemned the method of writing history which is chiefly concerned with the evolution of political institutions and ideas; and he

advocated instead one which would give us some picture of the evolution of the various human races. According to him, all wars, as well as all idealistic movements, are the result of physiological peculiarities. Their ultimate explanation is to be sought in the differences between the various races. Human races are as subject to natural laws as other living organisms; such laws are those of inheritance, of variation, of adaptation, of natural selection, of hybridization, of progress, and of decay.

Among these racial theorists were two schools:

The one believed that human characteristics are extremely constant, and that the most potent factor leading to variety has been interbreeding between different races. The consequences of evolution and of the struggle for existence received less attention from this school. The other believed that human characteristics are less constant. These were more in sympathy with the Darwinian view, and they attached great importance to the struggle for existence among mankind.

Ammon belonged to the first group.[1] He compared the bodily measurements of recruits drawn from various parts of Germany, and came to the conclusion that two distinct racial types had arisen as the result of intermarriage—a taller and a shorter race. Zograff, on the other hand, asserted that the Russian soldier is obviously the result of a cross between three types. Some members of this school have carried this idea of mixed races very far—De Lapouge, for example, who asserts that the town-dweller, like a mongrel dog, owes his existence to a mixture of many pure strains.[2] Members of both schools have developed these views until they reached the bizarre. We need only refer to the discovery of Lapouge that: 'Nearly all great men have belonged to the fair-haired, long-headed race—even when this does not seem to have been true of their relatives. I should not be surprised if the

[1] O. Ammon, *Die Natürliche Auslese beim Menschen*, 1903.

[2] G. de Lapouge, 'L'hérédité dans la science politique,' *Revue d'anthropologie*, 1888.

culture spread by some other races were to be traced one day to the admixture of some fair-haired long-headed elements with their more sluggish blood—an admixture veiled by the passage of time.

This same fair-haired race probably formed the ruling caste in Egypt, Chaldea, and Assyria; the fact is almost established for Persia and India, and is possibly true of Old China. Their importance in Graeco-Roman civilization is practically established, while in modern times the influence of the various living races is directly proportional to the number of long-headed blondes in the ruling classes of their population. To this race belong those Gallic and French elements on which the brilliance of France depends; the same people give life and movement to the masses in Germany.'

Anthropological theorizers of this type were very common in Germany. The majority of them used their theories to glorify Teutonism, and so have been called the 'Germanen theoretiker'—to these belong Woltmann, Houston Chamberlain, Lapouge, Günther, and many of the most virulent Antisemites.

It is difficult to estimate how much, if any, truth lies hidden in all this. Modern hybridization experiments have, as a matter of fact, shown that apparently unimportant characters are obstinately retained by the descendants of any such cross. Some of the views expressed by this school seem very fantastic. They teach, for example, that in the struggle for existence the Aryans have had the advantage of a well-developed brain from pre-historic times, and that the cephalic index of the earliest inhabitants of Germany is, on the average, six per cent. smaller than that of the modern Germans. They believe that Natural Selection is still at work separating the dark, round-headed, from the fair, long-headed populations. From the quotations given it is easy to see that these workers' idea of race is a somewhat loose one; it often coincides with the popular differentiation of men into 'fair', 'dark', and 'Jewish'. At the beginning of the Great War

these theories played their part in the agitation; the coming of peace damped the enthusiasm for such ideas, but they are still fairly common in Germany.

The question whether the crossing of two races is advantageous or disadvantageous is an old one. Both views find support. Some assert with Quatrefages that mixed races are quite as intelligent as pure ones, and point to the quickness of the Brazilian Creoles; others point to the supposed lower intelligence of these Creoles to prove the opposite view. Agassiz was among the second group. He thought that the unrest characteristic of Central America was the direct result of the mixture of races living there.

There are other theorists who agree with Darwin, and believe that there is great variability in human characteristics. Mankind is subject to Natural Selection, and this is the cause of his intellectual and structural progress. Darwin himself approached this point of view very closely when he reviewed modern societies, and discussed the future of mankind. He examined animal communities for suggestions as to the origins of human society. He pointed out that some altruism is shown by animals who live a social life; that among the savage horde the 'wise man' is revered, and that he dominates the horde. He pointed out that the possession of several 'wise men' gave the group a better chance in the struggle for existence; further that men are spurred on to new efforts by the praise of their contemporaries; thus their mental capacity increases. Even among civilized men he believed that the struggle for existence is still going on. He feared that too great care of the weak might lead to the downfall of the race, though he hoped that this danger would be partly averted, since in a highly organized society the weaklings are less likely to marry and procreate their kind.

Darwin thought that the law should step in to enhance this natural control of the reproduction of weaklings. He pointed out, also, that riches very often lead to dissipation and so to degeneration, and hence that the accumulation

of riches tends to undo its own evil effects. Civilization, since it provides mankind with better food, is advantageous to them. When he weighs the advantages of civilization against its disadvantages, he comes to the conclusion that it *does* make for progress, though rather slowly (*Descent of Man*).

Francis Galton, a relative of Darwin, turned his attention more definitely to this question of racial improvement. He was firmly convinced of the inheritance of acquired characters, and suggested certain factors that must lead to the progress of humanity. Among these were the exercise of both body and mind, and the conscious suppression of evil tendencies; the prevention of marriage between those afflicted with mental disease; the increasing tendency to later marriage, which he thought would prevent over-population. This work forms the basis of the modern eugenic movement, which started in America.

Similar observations still occasionally appear. Schallmayer, the German sociologist, pictures society as a collection of individuals, very unequally endowed, who 'struggle' for existence. He believes that Natural Selection is the only force making for progress. Therefore we must support it if we are to produce a humanity sound in mind and body. He enumerates (1903) the tendencies which aid the process of natural selection, and those which hinder it. He demands that less care be given to the weak, for those hygienic measures which save the weaklings, those laws which make it possible for criminals to produce children, weaken society. For this reason we must increase our sense of responsibility towards the coming generation, we must not abolish capital punishment, and we must follow Schopenhauer's advice and castrate habitual criminals.

Nietsche's philosophy, his differentiation between the morality of the leader and of the slave, his idea of a society produced by the 'will to power', his glorification of bodily strength—all this was a very great factor in the spread of such ideas. Bunge and his followers have devoted much

attention to the question of the healthiness or otherwise of human society. They assert that modern women are becoming less able to suckle their children. A thought on the same lines is Francis Galton's suggestion that the Spanish race has decayed because, during the years of persecution, it killed annually many thousands of its most independent thinkers. Plötz, Haycraft, Seeck, Reibmayer, Ribot and others have expressed kindred views.

XVI

DARWINIAN MORPHOLOGY AND EMBRYOLOGY

§ 1. *The Relation between Morphology and History.*

THERE are things which have no history, at least as far as our experience goes, crystals, for example. A crystal of rock-salt is always the same, whenever and wherever it may have arisen. When dissolved it disappears, leaving no trace which can be observed in any later formation; the Silurian rock-salt crystals appear to have been exactly similar to those which arise to-day. Before the days of Darwin many biologists had drawn attention to the analogy between crystals and living organisms. They thought living bodies equally absolute and eternal, embodying ideas which have endured unchanged since the world began.

When Cuvier introduced the study of palaeontology, when ideas about progress, borrowed from philosophy and political economy, began to enter biology, this conception of the organism as an embodied idea became very prevalent. The talk was now of the 'History of Creation', of the 'perfecting' of ideas, of the 'progress' of organisms. The living thing was no longer thought of as fixed and changeless, but became one of a stream of organisms, standing in a definite relation to those which had preceded and those which came after it. The idea here is not, however, one of actual material continuity; the continuity was rather an ideal one, representing the development of a thought, an idea.

We may contrast this with Darwin's conception. He, too, taught us to regard organisms as structures with a history, but as the product, not of an idea, but of a series of events in the real world. This was a great thought. We may study an animal as thoroughly as we please; we may compare it in the most detailed manner with other forms; but this will not enable us fully to understand its nature,

for it bears within it the traces of its past, traces which can only be revealed by historical study.

One result of Darwin's discovery—for it was indeed a discovery, was an attempt at a history of the world of living organisms. We must seek for the germs of the present creation in extinct forms and in long-vanished conditions. We must solve the problem of the origin of the vertebrates, discover the story of their evolution, get to know what forms went before them. For every animal, species, genus, or family we must find what it has inherited from the past, and what it itself has added to the story. We must write a history of the whole material creation, just as we would write the history of mankind.

This dream was not realized. It is true that Darwin opened up a new world to investigators. Columbus rejoiced because he thought, when he discovered America, that he had discovered a new route to worlds already known. So Darwin's followers gloried in having found a new way to explain already known facts. They did not originate any new science, any really historical study of morphology; they simply adopted all the old ideas, and explained them all by 'evolution', 'adaptation', 'inheritance', and 'the struggle for existence'.

There is a sense in which this Darwinian morphology is the exact antithesis of history. For the writer of history the date is the fundamental fact about any event. His first task is to place his fact in its proper sequence among historical events. He then tries to estimate its importance and its connexion with other events. If he does not know the time of the occurrence, everything he may say about it is necessarily vague and indeed can have but little value.

In the evolutionary study of morphology this sequence is reversed. The date of any biological event (e.g. the date when men first appeared on the earth), is purely a matter of conjecture. It is the relation of this incident to others, e.g. the similarity between Man and the apes, upon which the whole investigation is based. Huss lived before Luther. The writer of history cannot alter this fact, no

matter what his opinion of their relative importance. Whatever may be his view of history—whether he thinks there has been progress or degeneration, Huss is and remains a predecessor of Luther. There is no such established succession in the world of biology. It depends entirely upon our point of view whether we regard Amphioxus as 'older' or more primitive, or 'younger' and less primitive than—let us say—a lamprey.

Those who believe that there has here been progress call the lamprey 'younger', those who believe that here there has been retrogression call it 'older', than Amphioxus. Here is another even more striking example. Amphioxus is a fish-like animal which still exists to-day. The Icthyosaurus is a reptile long extinct. Nevertheless the Darwinians call Amphioxus the more primitive and Icthyosaurus the more advanced form. The uncertainty among evolutionists as to which forms are the more and which less primitive, is very great indeed. We do not know with absolute certainty the relative position (in time) of any form—not even of man himself.

It is generally supposed that the fishes are the most primitive vertebrates, and that the land-inhabiting vertebrates have come from fish-like ancestors. Dohrn, and, quite recently, Koken have declared, however, that they consider fish to be degenerate forms derived from ancestors who lived on the dry land. It is, then, only in name that Darwinian morphology and embryology can be called historical subjects.

They are not studies of the past history of modern forms of life; their methods are purely comparative—there is a search for homologies and analogies, just as there was before Darwin's time. This confusion of the comparative with the historical method began with Haeckel. His work dominated the field of speculation from about 1870 onwards—his theories of phylogeny, his law of biogenesis, his genealogical trees, his rejection of the 'type' system.

Haeckel, of course, had aroused considerable opposition, and workers, when they published their discoveries, their

confirmations and refutations of the theories that were being discussed, usually preferred to refer to Gegenbaur, to Ray Lankester, to Balfour, Hertwig and other less notorious scientists. These were men who had accepted Haeckel's views and had succeeded in presenting them in a form that made them suitable for teaching purposes—but they had not fundamentally altered them.

§ 2. *Transitional Forms.*

In the eighteenth century, and even earlier, philosophers often discussed the question of transitional forms. Leibnitz prophesied that one day an organism would be discovered in which the qualities of plants and animals would be found combined. When the fresh water polyp (Hydra) was discovered, Leibnitz's disciple Bonnet declared it one of those intermediate forms; to-day it is, of course, regarded as wholly animal. These workers had no idea, however, of historical evolution when they discussed transitional forms. We owe that idea, in its modern sense, to Lamarck and after him to Darwin, who held that since there are no species, genera, or orders in Nature, we must conclude that evolution has proceeded by very gradual steps.

The morphologists set to work to find forms intermediate between genera, and even between larger groups. Every new discovery of any such form was used to support the argument that nature proceeds gradually, and not by leaps. Lamarck had said that the Duckbill (*Ornithorhynchus*), an animal which had captured the imagination of his contemporaries, was intermediate between a mammal and a bird. The animal is shaped like an otter; like the birds, it has a toothless beak, a cloaca, and lays eggs; yet it is a four-footed, hairy mammal, and the young are suckled by their mother.

Lamarck's arguments are not convincing. An intermediate form, to bring assurance, should share the characters of the two groups which it links up to such an extent that it is impossible to say to which of the groups it belongs.

The duckbill does not fulfil this condition. It is unmistakably a mammal, although, in addition to its mammalian characters, it has a few that are avian and even reptilian.

From Lamarck onwards a succession of these intermediate types has been constantly discovered. Their fate has always been the same. Discussion has raged round them for a time, but eventually they have been included in one or other of the established groups.

The origin of the vertebrates has been a subject of controversy ever since the formulation of his theory by Darwin. At one time the discussion turned round the Tunicates or seasquirts. These animals have a body surrounded by a fleshy cloak or envelope, to which the name Tunicate refers. The mouth is situated at the anterior end of the simple body, and behind the mouth are the gill-slits. The alimentary canal is bent upon itself, so that it opens into a cloaca which lies near the mouth. The nervous system is reduced to a ganglion between these two external apertures, and the heart lies behind the gill-slits.

Cuvier and von Baer placed these animals among the invertebrates. Kovalevsky, the Russian naturalist, was the first to suggest that they had vertebrate affinities, but von Baer did not accept this view. He pictured the body of one of these Tunicates placed so that the mouth and cloaca were posterior, the nerve-centre ventral in position. Then the apertures in the Tunicate correspond in position to those openings beneath the shells of shell-fish through which water streams in and out. There is a certain analogy between the structure of the whole body in the two forms. Kovalevsky, on the other hand, compared these forms with Amphioxus, the simplest of all the vertebrates.

This latter is a fish-like animal about five inches long. It has neither bones nor limbs, and its internal structure is extremely simple. It was discovered by Pallas in 1774. He thought it was a shell-less mollusc. That it had certain affinities with the vertebrates was proved by Kovalevsky in 1864. He pointed out that there are many resemblances

between the developmental stages of Amphioxus and of the Tunicates. In both the nervous system is dorsal in position and is derived from ectoderm.

The young of the Tunicates are more highly developed than the adults. While adults are sedentary, the larvae are free-swimming and look like miniature tadpoles. In the tail region, ventral to the nervous system, there is a supporting rod similar to the notochord of Amphioxus. It had already been recognized that the notochord represents a vertebral column in its simplest form.

This work of Kovalevsky was confirmed and carried further by other investigators. They found many similarities between the early stages of both Amphioxus and the Tunicates. Thus:

(*a*) Both groups possess, when immature, a dorsal nerve tube opening by a neuropore.

(*b*) In both types the notochord lies beneath the nerve tube.

(*c*) In both the anterior portion of the alimentary canal bears gill-slits.

(*d*) In both forms there is a tail, posterior to the alimentary canal, in which there is a suggestion of metameric segmentation, both of the nervous system and of the muscles.

In spite of these similarities all workers do not agree that the ascidian lies between the vertebrates and the invertebrates. Semper suggested that the vertebrates have been evolved from the annelid worms. This theory depended chiefly on a supposed similarity between the excretory organs in the two groups. Hubrecht thought that vertebrate affinities were to be sought for among the Nemertean or Ribbon Worms. Patten would derive vertebrates from a form like the Kingcrab *Limulus*—a crustacean; others again saw the sought-for ancestor in Balanoglossus, and there have been many other suggestions.

The palaeontologists prided themselves upon discovering a large number of these intermediate types. Among these was Archaeopteryx, a creature supposed to link up

the birds and the reptiles. The extinct reptilian dinosaurs were also believed to be intermediate between the same two groups. The Dipnoi or Mudfish are a group, containing both living and extinct forms, which suggest how a transition may have occurred from fishes to amphibians. In 1901 Fleischman published a critical survey of all these 'intermediate forms'. He showed, from many instances, that the early enthusiasm had abated. The lack of success made him critical of the whole science of phylogeny. He went back to the ideas of Leibnitz, and asserted that problems relating to the origin of living animals do not come within the province of an exact science.

There could be no more whole-hearted condemnation of the search for transitional types. It may seem to us that Fleischmann's scepticism was too sweeping. He was dealing with the vertebrates, and the results obtained from the study of vertebrate phylogeny are certainly unsatisfactory. What, then, is to be our attitude to the phylogeny of the invertebrates? for it is well known that results obtained in this field of inquiry are even less definite. Concerning the vertebrates we know this much, at least—that the fish came before the reptile and the reptile before the bird and the mammal. The study of the morphology of invertebrates has told us still less about their phylogeny; we cannot even say which group came first.

A list of the more important forms which have figured as 'transitional' in Darwinian speculation is instructive.

Catallacta (transitional between the Protozoa and Metazoa). *Coeloplana Metschnikowii* and *Ctenoplana Kovalevskii* (Clenophora—Flatworms). *Trochosphaera aequatorialis* (Rotifera—Annelida). *Hexarthra polyphera* (Rotifera—Arthropoda). *Dinophilus* (Rotifera—Annelida). *Balanoglossus* (Echinodermata—Vertebrates). *Limulus* (Trilobites—Arachnids). *Peripatus* (Insects—Worms). *Scolopendrella* (Insects—Myriopoda). *Proneomenea* (Molluscs—Worms). *Phoronis* (Worms—Brachiopods). Tunicates (Invertebrates—Vertebrates). *Amphi-*

oxus (Tunicates—Fishes). Ganoiden (Sharks—bony fishes). Dipneusten (Fish—Amphibians). Dinosaurs (Reptiles—Birds). *Archaeopteryx* (Birds—Reptiles). Various extinct hoofed animals. The Gibbon; Pithecanthropus (The Ape-man), &c.

The results obtained from the study of plants are no better. We do not know any form which represents a real transition between the Algae and the Mosses, nor one between the Gymnosperm and the Angiosperm.

The belief that such forms ever existed has been frankly abandoned, and this has led to a theory of 'saltations'—of advance by sudden leaps.

Organs.

Biologists have made many attempts to discover the elements from which the bodies of plants and animals are formed. Goethe believed that the vertebra and the leaf, respectively, represent such elements; Schleiden saw the elements of structure in the cell; Owen held to the homologous organs as the unit structures.

There are in fact many ways of subdividing the organic body. Two in particular have found favour with anatomists—the division according to functional significance and the division according to morphological significance.

The fore-limbs of the horse, the whale, and the bird are morphologically equivalent, but they have very different functions. The fins of whales and fishes are modified to perform similar functions, though morphologically distinct. Even greater functional similarity, combined with morphological dissimilarity, is seen in the wings of birds and butterflies respectively.

Haeckel and Gegenbaur believed that homologous organs have been inherited from a common ancestor. If the primitive mammal was a four-footed animal, then the limbs of all mammals are homologous.

Similar organs for which we cannot postulate a common organ are, according to the same view, analogous; they

have been derived from different rudimentary structures, but, as the result of external conditions, they have developed a certain similarity.

The Darwinians considered that the following are special cases of homology or of analogy:

(*a*) *Analogous Variations.* 'Distinct species', according to Darwin, 'present analogous variations, so that a Variety of one species often assumes a Character proper to an allied Species, or reverts to some of the Characters of an early Progenitor' (*Origin of Species*). These characters are not such as are derived from a common ancestor; they have been acquired independently as the result of some similarity of inner constitution. Darwin gives as an example of this the variation in structure exhibited by our domestic pigeons. The most distinct breeds present subvarieties with feathers on the feet—a character not possessed by the original rock pigeon. This is an analogous variation in two or more distinct races, due to those races having inherited the same constitution and the same tendency to variation. The palaeontologists generally call this type of variation by another name; a series of forms which are structurally related, but have not acquired these structures from a common ancestry, is called a 'parallel series', or, following a suggestion emanating from Ray Lankester, 'homoplastic'. In recent times considerable importance has been attached to the study of Homoplasy through the work of H. F. Osborn, the American palaeontologist.[1]

(*b*) *Convergent* characters are, according to Darwin, those similar characters which are found in animals widely separated in systematic position, but evolved under the stimulus of a similar environment. The compound eyes of the Crustacea and of the Insects are examples of such characters, for presumably their common ancestor did not possess any such compound eye. Hence, although these eyes are similar in structure, they are not to be called homologous.

[1] Henry F. Osborn, 'Homoplasy as a law of latent or potential Homology,' *Amer. Natur.* 1902.

The precise difference between convergence, homology, and parallelism is, however, often difficult to define.

Latterly a new definition of convergence has been given which is rather different from Darwin's. The term is used to include any similarity of structure exhibited by widely divergent forms. Under this title are included, for example, the snake-like forms in the Permian Stegocephalia (Dolichosoma); in the eels and some other fishes; in those snake-like Amphibia, the Coecilia; in the slow-worm; in the cretaceous sea-serpents, and in the snakes themselves. Here, too, are included the various forms of teeth in different groups of animals; the different types of shell; different external coverings in the form of armour, horny scales, &c.

(*c*) Analogies were functional resemblances, in the eyes of the morphologists of the old school. Such similarities have not been thoroughly examined, and it is the general view that such resemblances are not important—that the similarity between the flight of the bat, the insect, and the bird is not a matter of very deep significance. The words 'flying', 'swimming', 'running' represent analogies of this type, and we speak of 'a similarity between the organs of flight', &c.

It may be that, in these phrases, we are only describing very superficial resemblances; perhaps a more thorough study of the flight of a bird, the gallop of a horse, the method of swimming of a whale would reveal some very deep-seated resemblances between these three apparently different motions—a resemblance possibly much greater than any which exists between the wing movements of a bird and a butterfly, or the swimming movements of a whale and a fish. We should then be able to discuss functional homologies just as we now discuss structural ones—we might even discover a deep-seated relationship between the two.

It seems strange that the Darwinists did not attach more importance to questions of physiology in discussing the significance of organs, if we recall their fundamental

hypothesis of the importance of adaptation. But the earlier morphological ideas were still exerting a great influence, and they believed that function could be deduced from the study of structure. We need only refer to a few scattered attempts to formulate a truly physiological interpretation of animal structure.

Dohrn, the founder of the Naples Zoological station, originated the hypothesis known as the 'Principle of Functional Exchange' (1875). This suggests that every organ has several innate functions—a main one and several other subsidiary ones. The limbs, for example, are primarily organs for walking, but they may serve for jumping, swimming, grasping, and so on. It may happen that the chief function falls into abeyance, while a minor one replaces it and becomes in its turn the principal function. This is followed by structural alterations in the organ concerned.

Dohrn did not develop his ideas further. He made no attempt to discover whether walking is really the primary function of all limbs; nor did he attempt to elucidate the relation between the so-called primary and secondary functions. His ideas soon passed into oblivion.

Julius von Sachs, the botanist, formulated a very similar theory (1893), which exerted a more lasting influence, and which we may still trace in modern theories of organogeny. Sachs believed that many qualities are latent in plants, which are revealed only under certain exceptional external conditions. He believed, for example, that the properties of epiphytic roots are possessed to some extent by all roots.[1] Sachs succeeded in making the potato, the vetch, the pea, and the maize live epiphytically. He thus demonstrated that a change in habit can be brought about by a change in external condition.

Sachs was convinced that many similarities between plants can be thus explained, different plants having re-

[1] Epiphytes are plants like the tropical orchids which live on trees without, however, being parasitic upon them. They live almost entirely upon what they can obtain from the air.

acted in the same way to the same external stimulus. He called resemblances thus produced 'parallelisms of habit'. Among his examples of this phenomenon are: the similarity between the leaves of the higher plants and similar structures of mosses and algae; the close resemblance between all the fleshy Cactaceae and the Euphorbias; the likeness between *Rosa berberidifolia* and the Barberry, between *Geranium triste* and the Umbelliferae. In these last two the resemblance is so close that we might almost speak of mimicry. Sachs also studied the problem of homology in the plant world; he considered that these 'phylogenetic parallelisms' were to be regarded as examples of analogous variation or homoplasy.

Strasburger was another botanist who studied similarities in the plant world. He distinguished between architypic and phylotypic homologies (1902). The first group have been inherited from a common ancestor. Cladodes (leaf-like branches), certain thorns, and some tendrils are examples of these architypic homologous structures; they are all modifications of one ancestral form—the shoot. Phylotypic homologies are those innate resemblances developed because the same law is acting —a law inherent in the organism. An example of this type of resemblance is that similarity of structure found among the growing points of so many multicellular plants. Strasburger made a third and final group of 'pantypic homologies'. These comprise those similarities of structure common to all organisms—the method of nuclear division, for example, which is substantially the same for all animals and all plants.

There has been a constant endeavour on the part of biologists to obtain some further analysis of the body of the living organism. As there was no possibility of abstract analysis, all that could be attempted was a rough empirical classification of those organs and tissues which are obvious to the eye.

Genetic morphologists, like their predecessors, made no attempt to formulate any abstract system according to

which the body might be analysed into its component parts. They were concerned with origins. In their discussions of the origin of the various animal groups they used the methods which were already in use. They compared organs, endeavoured to find out which were to be regarded as homologous, and to arrange the homologous ones in series, according to their degree of differentiation. Each series began with the simplest form and passed through forms of ever-increasing complexity, to end in the most complex. The brain was studied in this way, and the brains of the most diverse vertebrates were arranged in one ascending series. It began with Amphioxus, passed on to the Lamprey, and so it continued, to end finally with the human brain. Such a series was called a phylogenetic series—it was supposed to throw light on the evolution of the organ and was interpreted historically. The 'simplest' was thought to be the 'oldest' or 'original' form; the complex was called 'advanced' or 'more highly evolved'.

Following the lead of Gegenbaur some workers included in their series only mature organs; others included embryonic and larval forms; the two schools arrived at different ideas of the 'history' of the organ. Such series were constructed, not for whole organs only, but also of their parts, of tissues and of cells. Haeckel, for example, suggested a 'phylogeny of the tissues'; others wrote on the evolution of the pigments of the skin, on the evolution of sensory cells, of certain muscles, &c.

The Controversy about the Idea of Types.

Darwin's teaching destroyed the belief in the fixity and therefore the definiteness of species, genera, and families. It also destroyed the belief in natural 'types'. There was a tendency among his followers to increase the number of groups into which the higher animals were divided. This seemed somehow to lend support to the view that it does not matter whether we assume there are four or ten of them! We no longer believe that Cuvier, with his dis-

tinction of four main types, had attained complete finality; but the opposite view, that there are no types, has only gained a theoretic consent. In practice there was very soon a return to type teaching.

It is almost universally, though tacitly, assumed in biological text-books that organisms must have had a polyphyletic origin. We assume that there are various groups of plants and animals which are fundamentally different and which have been separated through their whole history. There is, however, no unanimity about the number of these lines of descent. Darwin originally assumed that there have been four or five such lines in each of the two kingdoms—plant and animal—but he did this without stating the reasons which led him to quote this number. Later he came to the conclusion that even these eight or ten ancestral forms had been originally derived from one primeval organism.

Haeckel also changed his views. He believed at first that living organisms had had a polyphyletic origin; but later he assumed a monophyletic one. He asserted that the two views are not fundamentally different. In this he was right to a certain extent, for later morphologists have not been able to give any definite reason for accepting the one view rather than the other. Nevertheless, modern scientists seem usually to favour the view that the animal world has had a polyphyletic origin. Julius von Sachs has shown very clearly that this polyphyletic theory is only Cuvier's old 'type' idea in a modern dressing. Von Sachs apparently did not realize that Owen had adopted the idea, and had given the name 'Archetype' to that fundamental plan which underlies each of the animal groups. This idea seems to have come back into Sachs' mind while studying the problems of phylogeny, and he formulated quite independently his definition of the *archetypus*, as he called it.[1] By this term he denoted a phylogenetic series of plants which have had a common origin; he assumed that each archetype is formed according to a

[1] J. Sachs, *Physiol. Notizen*, 1898.

plan which is characteristic of the group. This is only a repetition of Owen's definition of his types.

Sachs cites the following archetypes, i.e. plants which have formed separate evolutionary series since their initiation:

(1) Cyanophyceae (blue-green algae).
(2) Phaeophyceae (brown seaweeds).
(3) Rhodophyceae (red seaweeds).
(4) Conjugateae (and Bacillariaceae), including some green algae and others.
(5) Siphoneae (other green algae).
(6) Archegoniateae (which include almost all the green plants from the Algae (for example, Coleochaete) to the Phanerogams).

The theory of the polyphyletic origin of the animal world is only Cuvier's type idea given a new and historical interpretation. Our modern systems of classification are also very like those of Cuvier. Compare the modern subdivisions of the animal kingdom with Cuvier's types (Vertebrates, Molluscs, Articulata, Worms, Radiata). We do not find the word *type* in the modern classifications. The number of sub-divisions has been increased. We recognize an important innovation in the introduction of the Protozoa, but otherwise the whole picture fits very well into the frame of Cuvier's scheme.

I cite four examples of modern classification. The authors are all, with the exception of Fleischmann, upholders of Haeckel's views. Korschelt and Heider, for example, divide the animal kingdom into a large number of small groups—yet the only 'improvement', as compared with Cuvier's, is that they have increased the number of subdivisions. Cuvier's Radiata (groups 2–4, 14 and 15), Mollusca (groups 25–29), Articulata (10–13 and 16–24), and Vertebrata are still easily recognizable.

Purely morphological studies have fallen into disrepute to-day, and it is not only the Darwinian aspects of those studies which are out of favour. In the early days of Darwinism morphology was shaken to its foundations by the genetic theory. Haeckel infused fresh life into it when

R. Hertwig *Zoologie*, 1892.	Lang *Vergl. Anatomie*, 1894.	Fleischmann *Zoologie*, 1898.	Korschelt and Heider *Ver. Entwicklungs-geschichte*, 1890.
A. Protozoa	A. Protozoa	A. Protozoa	1. A. Protozoa.
B. Metazoa	B. Metazoa	B. Metazoa	B. Metazoa.
		Spongiae	2. Porifera.
	Coelenterata	Coelenterata	3. Cnidaria.
			4. Ctenophora.
	Plathelminthes	Platodes.	5. Plathelminthes.
			6. Orthonectida and Dicyemida.
		Nemertina	7. Nemertini.
			8. Nemathelminthes.
			9. Acanthocephali.
		Rotatoria	10. Rotatoria.
Vermes	Vermes	Annelides	11. Annelides.
		Sipunculida	12. Sipunculida.
			13. Chaetognatha.
			14. Enteropneusta.
			15. Echinodermata.
	Arthropoda		16. Crustacea.
			17. Palaeostraca.
			18. Arachnoidea.
			19. Pentastomida.
			20. Pantopoda.
			21. Tardigrada.
			22. Onychophora.
			23. Myriapoda.
			24. Insecta.
			25. Amphineura.
			26. Lamellibranchiata.
			27. Solenoconcha.
			28. Gasteropoda.
			29. Cephalopoda.
			30. Phoronidea.
		Bryozoa	31. Bryozoa ecto-procta.
		Brachiopoda	32. Brachiopoda.
Echinodermata			33. Endoprocta
Mollusca	Mollusca		
		Tunicata	34. Tunicata.
	Echinodermata	Echinodermata	
	Tunicata		
		Mollusca	
Arthropoda		Arthropoda	
Vertebrata	Vertebrata	Vertebrata	35. Cephalochorda.
			36. Vertebrata.

he began the construction of genealogical trees, and for a time every morphologist followed his example.

To-day this branch of science is paying the penalty for this; it is accused of inexactness—the accusation levelled against the whole Darwinian teaching. Physiology is the modern science; it has long been threatening to displace morphology altogether.

Embryology in the Darwinian Period.

Darwinian embryology was completely dominated by the fundamental law of biogenesis. The embryologist's task was to discover the past history of each organism from its ontogeny. It is not possible to elucidate this history directly, but we can do so indirectly if we accept Haeckel's law that embryonic development is but a shortened and modified repetition of phylogenetic evolution.

Francis Balfour, the sagacious English scientist, thus described the task of the embryologist (1880):

'In the department of Phylogeny the following are the more important points aimed at:

(*a*) To test how far Comparative Embryology brings to light ancestral forms common to the whole of the Metazoa . . . by comparing the embryos and larvae of the different forms.

It supposes the ovum itself to represent the unicellular ancestral form of the Metazoa, and hence deduces that all the Metazoa have descended from an Amoeba-like form.

(*b*) To see how far modern larval forms may be interpreted as the ancestral type—as reminiscent of the progenitors of the group. For example, the trochosphere larva was considered by Ray Lankester to be common to the Molluscs, Vermes, and Echinodermata, and hence our phylogenetic studies lead us to affirm that the Trochosphere may have once existed as an adult animal, and that from it all the above groups may have evolved.

(*c*) To see how far these larval forms agree with living or fossil forms in the adult stage. When, for example, we find that the rotifers "have many points of resemblance to the trochosphere", we infer that the trochosphere also gave rise to the Rotatoria.

(*d*) To find how far organs appear in the embryo or larva which

either atrophy or become functionless in the adult group, as do the gill-slits in the embryos of the higher Craniates.

(*e*) To find in how far such organs represent structures inherited from the ancestral form, and in how far they represent adaptations to new conditions of life.

If these organs are found in a permanent condition in some lower form, performing some definite function, then we may conclude that the organs now only present in the embryo once passed through this stage of development.

The second department of comparative embryology is concerned with the origin of organs . . . with the origin and homologies of the germinal layers . . . the origin of the primary tissues and their relation to the germinal layers . . . the origin and development of the more complicated organs and systems of organs.'

This programme was followed by the embryologists. Using comparative data, they constructed their genealogical trees. They also tried to find out from which of the cells of the segmented egg each organ and tissue of the body was developed. Many organs and tissues were invested with a temporary importance; they were believed to represent some phylogenetically transitional stage in the evolution of the animal world.

The gastrula stage, to which we have already referred in our chapter on Haeckel, became prominent in discussion. The larvae of the marine Planarians; the larvae called *Pilidia* of certain nemertine worms; the larva called a *Trochosphere*—all these, and many others, have been discussed as the reputed ancestors of a larger or smaller group of organisms.

Among embryonic organs which were considered very important were the segmentally arranged glands found in certain worms (from these, glands found in arthropods and vertebrates were believed to have evolved); the cleft foot of certain crabs; the small number of segments in the larvae of certain millipeds (these larvae were thought to be the ancestors of the insects); the gill-slits in the higher vertebrates, and so on.

The speculations contained in the second volume of

Balfour's *Embryology* (1880) are based upon the theory of embryonic layers. We have seen already that both the gastrula and the hypothetical gastraea consist of two embryonic layers—ectoderm and endoderm. Wherever these layers occurred they were held to be homologous, i.e. inherited from a common ancestry; and those tissues and organs which were derived from the same embryonic layer were regarded as related structures.

Thus the nervous system and the epidermis both originate in the ectoderm, and so were thought to be more nearly related to each other than to bone and muscle, which develop from the mesoderm. The beginning and end portions of the alimentary canal were regarded as differing fundamentally from the middle portion, since they are ectodermal in origin, while the latter is derived from mesoderm.

Spiders and insects are nearly related groups, and their excretory organs (the so-called Malpighian tubules) are very similar in appearance. Yet since, in the former group of animals, these develop from the endoderm, while in the latter they arise from the ectoderm, they could not be regarded as homologous structures, in spite of their close morphological and physiological similarity.

This theory of the germinal layers was completed by the theory of the coelom, promulgated by the brothers Oscar and Richard Hertwig.[1] The simplest multicellular animals originate from two embryonic layers—ectoderm and endoderm. But in the course of development there arises, in the embryos of the higher animals, a third layer—the mesoderm. This mesoderm arises in some forms, as a pair of diverticula of the endoderm, the so-called coelomic sacs. These sacs represent the beginnings of the body cavity, the so-called coelom. The Hertwigs called a mesoderm of this nature a 'mesoblast'. In other cases no coelomic sacs arise, but ectodermal or endodermal cells (there is no definite rule) pass into the space between these two

[1] O. and R. Hertwig, *Die Cölomtheorie, Versuch einer Erklärung d. mittleren Keimblattes*, Jena, 1881.

germinal layers and form there the so-called *mesenchyme*. In other cases both mesoderm and mesenchyme may be present.

The Hertwigs divided all multicellular animals into those which form mesenchyme only and those which form both mesenchyme and a coelom. In addition to this classification they suggested that the coelom was originally an organ of secretion, and that it afterwards developed the power to form reproductive cells. There was much discussion on the distinction between those animals which possess a coelom and those which do not; as to which form of coelom is the more primitive—that arising as a diverticulum or the type which is formed by cells of the ectoderm; also which function is the more primitive—the secretory or the production of the sex cells.

Bunge, the physiologist, took all the facts known about the chemical composition of the animal body, and applied to them Haeckel's 'Fundamental Law of Biogenesis'. Common salt is a necessary ingredient of animal food. He tried to explain this by the theory of evolution on the ground of descent. He showed that the amount of salt any body contains depends on the nature of its surroundings. The only plants rich in sodium chloride are marine plants, sea-shore plants, and the plants inhabiting salt steppes. Chenopodium and Atriplex are exceptions to this rule. These flourish in waste ground rich in salt, and are closely allied to the plant inhabitants of salt steppes. Among invertebrate animals marine creatures and their nearly allied species on the dry land are the only ones with a large salt content. Insects, which are typical land animals, contain extremely little salt. Land-inhabiting vertebrates contain a large amount of salt. This characteristic, according to Bunge, is one inherited from marine ancestors. If this be true, Bunge continues, we should expect that the younger any vertebrate animal is the richer its body would be in salt. He asserts that this is the case. The mammalian embryo contains more salt than does the newly born animal, and the

body contains less chlorine and potash as development proceeds.

Speculations of this nature reached their culminating point about 1880 and then rapidly declined in importance, as certain abnormal phenomena of development began to attract attention.[1]

Haeckel and the earlier embryologists knew of many exceptions to the ordinary course of development, but they were content to call these 'adaptations to special conditions'. They seemed to think that everything that was obscure could be thus explained. All such exceptions were classed together as cases of 'a-typical development'; among these they distinguished between the following special processes:

(*a*) *Regeneration*, by which wounds are healed, and lost parts of the body replaced.

(*b*) *Fission*, by which process some creatures multiply, e.g. certain worms, which, however, also have a sexual process. The body narrows at one place, and separates into two portions, each of which is capable of becoming a new and complete animal.

(*c*) *Budding*, by which an animal, such as the freshwater Polyp, forms a new and separate individual from a 'bud' on the parent body.

The study of such phenomena led to the development of a new branch of science—experimental morphology, which drove descriptive embryology off the field.

It was very difficult to reconcile the phenomena just enumerated with the fundamental assumption of Darwin and Haeckel, that the form of an organism is the result of a series of changes, which have been in progress for millions of years. The fact that an animal can replace a

[1] This revolution in the ideas of embryologists is made very clear by a study of the great text-book of comparative embryology published in Jena by E. Korschelt and K. Heider. The first, the part dealing with special embryology, is completely dominated by the theories of Haeckel. It was completed in 1890. The second, the 'general' part, was finished in 1902, and it does not contain any Darwinian discussions, but is concerned with the phenomena of fertilization and with experimental embryology.

lost limb by a new one is as great a blow to Darwinism as is a 'faked antique' to the lover of antiquity. More recently, facts derived from a merely descriptive study of the processes of development have also been cited in disproof of Haeckel's fundamental law.

Mehnert has suggested that it should be replaced by his principle of 'Kainogenesis'. According to him, homologous organs are formed in each developing animal at a rate specific to and quite characteristic of the particular type of animal. The Darwinists asserted that the heart is only a more highly differentiated portion of the great blood-vessels, and it should therefore, according to Haeckel's law, be formed after these. Nevertheless we know of many vertebrate animals in which it arises before the blood-vessels. Phylogenetically, the mammary glands are supposed to be derivatives of the ordinary skin glands, and yet ontogenetically they arise long before the skin glands.

According to Mehnert the rate of ontogenetic development does not depend upon the phylogeny of the organ, but upon its degree of differentiation. The thigh-bone is, for example, the organ in man which has acquired the greatest ability to grow in length. It develops very quickly in embryonic life. The smallest human member examined by Mehnert was the first phalange of the thumb, and he found that this grows most slowly.[1]

Plant embryology was not as much influenced by Haeckel and his views as was zoological theory. From the very beginning von Sachs led botanical speculation into simpler channels. He believed in direct observation rather than in philosophic abstraction, and he regarded development merely from the point of view of the gradual formation of new organs. He distinguished four phases in this process:

(*a*) The formative period, due to the activity of the apical meristem, or growing point. Here the number and position of the organs are determined, but not their form.

[1] E. Mehnert, *Biomechanik, erschlossen aus dem Prinzip der Organogenese*, 1898.

(*b*) The embryonic stage, when those parts of greatest morphological importance are laid down.

(*c*) The elongating stage, when this rudiment is enlarged and assumes its final form.

(*d*) The maturation period, during which the tissues reach their final form. Sachs agreed with Haeckel's fundamental law of biogenesis in one point: he asserted that the earlier an organ is laid down at the growing point the greater is its phylogenetic importance.

There were other botanists, of whom Strasburger is an outstanding example, who thought that this agreement went much further.

XVII

THE GEOGRAPHIC DISTRIBUTION OF ANIMALS AND PLANTS

§ 1. *Humboldt classifies Plants according to their Habitat.*

EACH race of mankind inhabits its own definite territory, and so do the various species of plants and animals. In one land lives the elephant, in another the gorilla; the mountain pine and the cedar inhabit different areas. Buffon, in his popular *Natural History*, gave the impulse which led to the study of many biological problems of this kind. He was the first to ask why the elephant inhabits the warmer regions of the Old World, while one tapir is found in the East Indies and another in South America; why, in short, the distribution of animals over the surface of the globe does not depend on climate alone. After Buffon, the Russo-German traveller, Pallas, was the worker who added most to our knowledge of animal distribution. His discovery of the rhinoceros and the mammoth, buried under the Siberian ice, attracted wide notice.

Much attention was given to these problems by that versatile German savant, Alexander von Humboldt (1769–1859). He was a dispassionate investigator; his riches, his public position, and the long voyages he undertook brought him such fame that to many the whole period will appear as 'the Humboldt period'. Nevertheless, he was essentially unproductive. His genius was not creative; he hoped to win distinction as a philosopher and a scientist, and yet he had no talent for philosophy, no power to deal with facts in a lively and original way. In addition to this he had a tendency to aestheticism which reveals itself in his physiological, geological, and geographical writings.

Humboldt's scientific reputation was chiefly due to his geographical work. He loved travel, and in pursuit of his

scientific inquiries he visited Asia, Africa, and more particularly equatorial America. In his popular *Ansichten der Natur* he describes the impressions called forth by great mountains, by the river Amazon, by the primeval forest and the desert. The characteristics of each district are best described by the plants growing there; hence Humboldt gives in his book a plant physiognomy, dividing plants into nineteen groups, according to the impression they made. His groups are: The *palms*, which he regards as the tallest and most magnificent of plants; the *banana-like plants*, with low-growing stems, rich in sap, which bear an apical crown of leaves; the Malvaceae and Bombaceae —plants with enormously thickened stems, the leaves heart-shaped or lobed, and covered with fine hairs; *mimosas; moorland plants; cactus-like plants; orchids; casuarinas*—trees whose branches resemble, in their general habit of growth, the branches of an equisetum; *conifers; forest trees* with stems full of sap and with large leaves with prominent veins; *lianes; aloes; grass-like plants; ferns; liliaceous* plants; *willow-like* plants; plants with the *myrtle* habit, with the *laurel* habit, &c.

Humboldt believed that the task of describing these forms was one for the landscape artist rather than for the scientist; nevertheless the latter will find it an interesting exercise to examine this classification in greater detail. Humboldt's ideas are in fact still of value, although they receive little consideration.

Another of Humboldt's attempts seems to have been completely forgotten, namely, his attempt to discover the causes of the present geographical distribution of plants and animals. Ten years before Darwin's work appeared Humboldt very strongly criticized

'those who like to dream of a gradual transformation of species, who look upon those cases where each island of a group has its own special parrot, as cases where there has been a modification of species; . . . who attribute the wonderful uniformity of the above numbers (the numbers of species which inhabit the various geographical regions) to a migration of the same species into those regions; this

species having in the course of time been so changed by climatic conditions that in the end it has apparently replaced its progenitor.'

Why, then, have the common heather and the ordinary oak not spread eastwards across the Ural mountains? Why are there no Rosaceae in the Southern Hemisphere, and why so few calceolarias in the Northern? Humboldt gives an explanation of such facts of geographical distribution. He believes that the number of species in each order is determined by a mathematical law, and that this law remains constant throughout any geological epoch. Once we have shown, as Humboldt showed, that in the Temperate zone $\frac{1}{8}$ of all phanerogams are Composites, $\frac{1}{12}$ are grasses, $\frac{1}{18}$ are Leguminoseae; then, he asserted, it should be possible to take any one area—viz. Germany—to determine the number of species belonging to any one of the above orders which occur in that area, and from this to make a rough estimate of the total number of flowering plants in the area, and of all the other groups of plants as well.

To take an example: There are many species of Gramineae, of Umbelliferae and Cruciferae, of Compositeae, Leguminoseae, and Labiateae, which are very common in Germany, but which do not occur in France; and yet the relative numbers of the above-mentioned families are practically identical in the two countries. Hence the German species must be represented in France by other species of the same family.

Agassiz devoted much time to investigating problems of geographical distribution, and arrived at a similar standpoint to Humboldt. He was convinced that there is some general law, or, as he would have expressed it, some Divine Idea, which determines the number of existing individuals, species, and genera, as well as the limits of their distribution. He believed that there is a direct numerical relation between the number of carnivorous animals and the number of their prey. Some forms are very rare, others extremely common. This rarity or abundance is a charac-

teristic of the different forms, and is by no means due to mere chance.

§ 2. *Darwin's Historical and Experimental Conceptions applied to the Facts of Distribution.*

Darwin's ideas gave impetus to the study of biological aspects of geography. It was, indeed, a geographical fact which led him to consider the question of the origin of various species from a common ancestor, namely, the observation that the animal inhabitants of certain South American islands, though very similar, are yet not identical. Darwin ascribed this similarity to the fact that the animals were descended from common ancestors, but had developed differently in different environments. His views were not related to those of Humboldt, however. He did not pay any attention to Humboldt's 'types', nor to his 'numerical law', nor did he believe that there is any such simple relationship between the evolution of the organism and the area it usually inhabits. When he discusses the geographical distribution of plants and animals he does not suggest any such direct interaction between them and their environment (that desert plants exhibit certain characteristic features, for example, while aquatic plants exhibit others). On the contrary, one of his leading themes is that the physical factors in the environment are not sufficient to explain the infinite variety of forms that inhabit these different areas. He suggests that some of the links which exist between the living organism and its surroundings can only be explained by an appeal to past history.

To give an illustration: The marsupials are only found in Australia and its adjacent islands and in South America. There are no causes, climatic or other, to which these facts of distribution can be satisfactorily attributed. But history gives the clue. Australia and South America were once connected by a land bridge which has long since disappeared. When this existed there was, however, no

land connexion between North and South America. Hence similar animals are found even to-day in Australia and in South America—animals which do not occur in North America.

Gingko is a peculiar tree which has often been cultivated of late years in Europe. It possesses only very distant relatives among living plants—the modern conifers. The fact that this tree is found wild in China and Japan only can be best explained on historical grounds. This family of trees once contained many species, and was spread over the whole world. The family is dying out; Gingko is the last survivor, and is itself perhaps doomed to extinction.

Inspired by such ideas, Darwin asserted that the facts of geographical distribution can only be explained historically, and that this is in itself a proof of the correctness of his theory. In actual practice he did not devote much attention to these historical explanations; he merely cited them to prove that the present distribution of plants and animals over the surface of the globe is not due to some predetermined plan. This argument was accepted, simply because his opponents were not inclined to attack it.

Darwin was always seeking for some secondary explanation of modern conditions. In pursuit of this end he focused his attention on the means by which an animal or plant is able to migrate from one district to another. He showed that some seeds retain their power of germination, even after long immersion in water; that swamp birds carry eggs and seeds adhering to their feet from one swamp to another; that the wind, ocean currents, and even glaciers can carry organisms over long distances, and so make it possible for similar animals and plants to be found in very widely separated areas. He supposed that large stretches of ocean, climatic barriers or widespread deserts would hinder migration; hence these tend to become boundaries between animal and plant communities.

It was thus that Darwin analysed the facts, and he explained the present geographical distribution of animals just as we explain the present distribution of human races.

Each species arose at some definite spot, as the offspring of one pair of parents. From that centre the descendants either spread out on all sides, so that the fatherland became the centre of the area inhabited by them, or they migrated into a new area. The prevailing distribution is the result of consolidation after long epochs, during which there was a continued and highly complicated succession of origins, migrations, and dispersals, all interwoven. Meanwhile sub-species were separated off from the parent species, and these became new and independent species in their turn. This is why the present distribution of animals and plants is so confused; this is why we meet nearly related forms in the same or in adjacent areas; this is why any boundary between two areas is usually a boundary between living forms which have little in common; for this reason high mountain chains, deep seas, long-established deserts are boundaries between quite distinct fauna and flora.

The fundamental assumption which underlies all Darwin's ideas about geographical distribution is that every species arose only once, and only in one place; hence that it had only one ancestral home, from which it spread further afield. Darwin believed, further, that nearly related forms always arose near one another; hence they inhabit neighbouring lands, unless they have wandered further afield in the course of migration.

§ 3. *Wallace's Zoological Regions and their Botanical Equivalents.*

Wallace used the facts of animal distribution rather differently from Darwin, in deducing from them support for the theory of evolution. He did not pay much attention to the small and obvious agents by which existing organisms may possibly be transported from one part of the earth to another. His attention was focused upon the broad question of the modern boundaries between the various animal types, and he sought for the explanation of

modern conditions in the geological records of the past. In 1857 Sclater had divided the world into regions according to the distribution of mammals. In close connexion with this work, Wallace divided the earth into six regions, each defined by the characteristic mammals inhabiting it:

The *Palearctic* realm, including the whole of Europe, the north of Asia as far as the central Himalayas, and Africa north of the Sahara.

The *Nearctic* region, embracing all North America to the edge of the Mexican plateau.

The *Indian* or *Oriental* region, consisting of Asia south of the Himalayas, and of the Sunda Islands (except Celebes and Lombok).

The *Ethiopian* region, including Africa south of the Sahara, Southern Arabia, Madagascar, and the Mascarene Islands.

The *Neotropical* region, from the northern border of Mexico to Capetown.

The *Australian* area, embracing Australia and the adjacent islands south-east from Celebes and Lombok (inclusive), together with New Zealand and Polynesia.

Trouessart, the French geographer, added two more regions: the *Arctic*, including those northern areas with an average annual temperature which is below 0° C., and a similar *Antarctic* area.

Wallace compared the forms inhabiting these different regions, to find which showed any anatomical relationship. From these facts, and from palaeontological evidence, he suggested avenues of migration along which the animal world had probably spread. In this work he assumed that each species had originated in one region only. (We have seen that Darwin made a similar assumption.) He showed that there is, for example, a marked analogy between the fauna of Europe, Asia, and North America. How was he to explain the fact that the same beaver is found in Europe and in America, that in both regions we find a similar bear or similar cattle (*Bison europaeus* and *B. americanus*), that very similar plants are also found in both? Only by the assumption that formerly, in some not-far-distant geological epoch, the old world was united by a land bridge to the

new world, and that over this plants and animals had passed. For similar reasons Wallace assumed that at one time Africa was connected with Madagascar and Ceylon, on the one side, and with South America on the other.

Wallace's method found many imitators, and, in particular, it dominated zoological geography.

It has extended, too, among botanists, and Drude's floristic areas became as important for botanists as were Wallace's regions for zoologists. Drude distinguished:

A. *Oceanic Floras*, which include those of the littoral, where marine algae and the so-called sea-grasses are found.

B. *Dry Land Floras.*

(*a*) The Boreal Floras.

1. The Northern Temperate belt; Northern and Central Europe; Northern Asia; the most northerly regions of America. Here there occur woods, grasslands, tundras, and so on.
2. The central areas of North America.
3. Eastern Asia.
4. Central Asia.
5. The Mediterranean area.

(*b*) The Austral (southern) floras.

6. The Antarctic areas.
7. New Zealand.
8. South America (the Andes).
9. Australia.
10. Southern Africa.

(*c*) The Tropical floras.

11. Tropical America.
12. The flora of India.
13. The flora of the Islands lying to the east of Africa.
14. Tropical Africa.[1]

§ 4. *A Return to the Study of the Direct Dependence of the Flora and Fauna upon the Environment.*

In recent times the geographical methods of Darwin and Wallace have been gradually superseded. We have, however, retained their fundamental axiom, that some

[1] O. Drude, *Die Florenreiche der Erde*, 1889.

knowledge of the facts of palaeontology is necessary before we can understand modern problems of distribution.

But while general interest in such matters has waned, there has been a gradual revival of interest in the question of the direct relationship between the organism and its environment. This marks a return to the tendencies of pre-Darwinian times. Darwin's most characteristic assumption, that each species arose once and in one area only, is being challenged. Further, it is alleged that Darwin attached too much importance to the phenomena of migration. Migration did not consist so much in a definite leaving of the ancestral home as in a fluctuation here and there under the drive of climatic pressure; the total effect would not lead to any great regional changes of fauna.

Bird migrations have been studied by recent workers, with these objections in mind. Our birds move towards the south, but that is only a part of a more widespread migration. In every region, from the extreme north to the Equator, birds are on the move. They stream in one direction in autumn; in the opposite direction in spring. H. Friedmann has developed certain views about geographical distribution which are absolutely opposed to the assumptions made by Darwin.[1] He goes back to the ideas of Agassiz, ridiculed by the Darwinists. The home of each species is, according to him, an important characteristic of that species, and is not to be explained by migrations, by dispersal, or by any external circumstance whatsoever. He believes in the spontaneous origin of each species, and hence that each stands in the most intimate relationship with its natural surroundings; there are psychical bonds between the milieu and the organism! This author stands quite alone in these views.

Botanists never got as far from the ideas of Humboldt as did the zoologists. The plant world was so simply and so obviously dependent upon its surroundings. Schimper in his *Physiological Geography of Plants* (1898)[2] indicated the

[1] H. Friedmann, *Die Konvergenz der Organismen*, 1904.

[2] A. Schimper, *Pflanzengeographie auf physiologischer Grundlage*, 1898.

awakening of new interest in this subject by his very title. It is significant that the author calls himself a Neo-Lamarckian.

Among zoologists in general the direct physiological dependence of the animal upon its surroundings has been little regarded, although undoubtedly the animal world could also be divided up into 'formations' determined by external conditions. Entomologists, however, have always studied insects in relation to their environment. They distinguish between insects which live in mud, which live underground, and so on; further, between nocturnal and diurnal insects, between hopping, running, and creeping insects, &c.

The same mode of life is seen repeated in many heterogeneous animals. This seems to suggest that the possible ways of living are not unlimited, but are determined by unalterable laws, even as bodily structure can only vary within certain limits. The habits of life of the mole are repeated by the mole-cricket (*Gryllotalpa*); those of the termites by the ants; the gait of the kangaroo is seen again in the jerboa (*Dipus*), and such examples could be multiplied.

Modern work on ocean fauna, on freshwater and on cave animals, makes it apparent that there has been some recession from the Darwinian view of distribution. There is less tendency to study one kind of animal and its relation to others occupying the same or different territory. This type of work is replaced by study of the whole group of animals inhabiting any one area and of the common characteristics exhibited by the group.

The most favoured field for this work is that offered by the ocean deeps and their fauna. In these depths animals live under peculiar conditions. There is here no light of sun or star, neither the blue heavens nor green plants; here no noise penetrates, no wave moves, there is no day or night—all seasons are as one. Temperature is invariable and near 0° C., and there is a constant pressure of over 100 atmospheres.

In this realm of eternal darkness and silence live fishes, molluscs, crabs, echinoderms, but no plants. Dead diatoms and the corpses of animals sink gradually from the more superficial layers, and afford the only source of nourishment for certain of these deep sea forms, while the rest are carnivorous and live on their neighbours. Some of these animals are very ancient forms which have long ago disappeared from the shallower parts of the ocean. Among these are numerous crustacea and quaint creatures called sea-spiders, whose precise relationships are uncertain; the sea-hedgehog (*Calveria*, which is known as a fossil also), feather-stars (crinoids); the degenerate sea-squirts; *Terebratula*, found attached to rocks at a depth of 4,000 metres, which was living in Jurassic times.

Some of these animals—especially the crabs—are blind. Most of them possess large and peculiar eyes, which often project from the head like telescopes; many have peculiar luminous bodies which give out a greenish light. Some are colourless. The deep-sea fishes, however, are usually dark grey or black. Some deep-sea crabs are crimson. Some creep over the floor of the ocean, or adhere to it.

Unicellular animals (Foramenifera), beautiful sponges and polyps, showing wonderful colouration, echinoderms and crabs are among the deep-sea fauna. Some of these creatures float in the water, and never come into contact with the solid earth; others crawl on the bottom.

Marvellous are these deep-sea animals; still more marvellous the fact that there is not one order of animals known to us from the ocean depths alone—although the conditions there are so utterly different from those at the surface. The forms of organic life develop within such strictly defined limits that even such very different environmental conditions have not altered more than minor details in the structure of these animals. The theories of both Lamarck and Darwin are powerless to explain these facts.

XVIII

PALAEONTOLOGY

§ 1. *Geological Succession.*

THE history of life passes from unknown beginnings, through long epochs from which only very questionable traces of organic life have come down to us, then on to the periods when fossils begin. These preserve for us what are, in a sense, printed records of that past life. We divide this history of organic life into periods—ancient (palaeozoic), the middle ages (mesozoic), and recent (caenozoic); to these must be added the most recent period of all, during which man has existed, the anthropozoic. These periods are subdivided, and the subdivisions bear special technical names.

We do not know for how long each period endured, nor how old our planet is. During the eighteenth century most geologists were still influenced by the Biblical teaching, according to which the earth was first created 6,000 years ago. Even at that time, however, Buffon estimated that its age was much greater; he suggested 65,000 years, but was not able to fill in this long period with any definite events. It was the English geologist, Hutton, who first effectively refuted the estimate based on biblical statement. He began with the assumption that all changes in the earth's crust are the result of causes like those in action to-day, and that colossal upheavals merely represent the combined effects of a series of smaller changes. He was thus forced to assume that enormous periods of time had elapsed, during which the large mountain ranges had been thrown up, the coast-line had undergone great alterations, and alluvial deposits, often thousands of metres deep, had been formed.

Charles Lyell adopted these assumptions of Hutton. He taught that the earth had been in existence for millions of years, and that small changes had been constantly in

progress throughout. Darwin and his followers accepted this view, but spoke not of millions of years but of hundreds or thousands of millions during which our planet had endured. The demonstration of the fact that life upon the earth is enormously old has been compared, not inappropriately, with the revelation of the enormous vistas of space in which float the stars.

Unfortunately we do not know even approximately what is the age of life as such upon the earth, nor what has been the duration of the separate epochs. But palaeontology agrees with human history in this—that the earlier and doubtless more fundamental modifications have taken vastly longer than the later no less striking but probably less fundamental changes. This may be expressed by saying that the earlier periods are longer, and the periods become shorter as we get nearer to our own time.

Historians of the past study the documents which have come down to them, while palaeontologists reconstruct the history of life from the fragments in certain kinds of rock which they have reason to assume are of organic origin. From the impressions and the bones of once living forms they reconstruct the appearance of extinct animals; while, from the sequence of the layers of the earth's crust, and from the nature of the fossils these layers contain, they deduce the surroundings in which the animals and plants of each epoch lived. They have come to realize that, in a series of consecutive epochs, the earth was inhabited by quite different plants and animals.

Just as at the very dawn of human history we meet with various races at different stages of development, so in our palaeontological studies we find that the oldest known animals are very varying and fairly advanced forms —Crustacea, Brachiopods, Molluscs, and the like. Among mankind the lower races have always existed side by side with more advanced ones, and they still continue to do so. Progress does not drive the whole human race forward at once, it seizes now upon this people and now that. Some peoples have remained for untold ages at the same

level of existence. Some advance to a certain level and then cease to develop, even retrogress, ultimately to disappear from human history. So too in organic nature. Some forms (Algae and Brachiopods, for example) have existed ever since our earliest records of life without undergoing any marked alteration. Other forms advanced for a time and then degenerated; many of these have disappeared completely (Trilobites), others drag on as an insignificant remnant (Clubmosses). There are others, again, which in the beginning consisted of a few types only; from these evolved an untold wealth of varying forms, which in turn became much fewer, without, however, disappearing altogether. The Reptiles live on a mere shadow of their former selves, for they were the dominant forms in the Mesozoic fauna.

It is difficult to deduce any law of development from the kaleidoscopic changes in the earth's history. In this connexion Huxley pointed out a strange fact. Life has existed on the earth for millions of years, and there have been millions of different forms of life. Yet, great as is this variety, it is confined within narrow limits. He who seeks among extinct animals for forms wholly different from those existing to-day is doomed to disappointment. There is no single large subdivision of the plant or animal kingdom known only from fossil representatives; all clearly reveal their relationship to existing forms. On the other hand, some forms, notably the Brachiopods, have existed unchanged through untold ages.

The most favourable evidence that there has been a progressive evolution of life on the earth is afforded by the history of vertebrates. No vertebrates have so far been found in the oldest strata which furnish fossils. Soon, however, fishes appear. This lowest group of vertebrates has continued to this day. It is difficult to say whether they have progressed since they appeared. The simplest fish-like forms—Amphioxus and the river-lamprey—are not known as fossils and are very specialized and probably degenerate, while the mudfishes (Dipnoi), which are re-

garded by some anatomists as the highest group of fishes, are found as fossils in the Devonian—that is, they existed in the middle of the Palaeozoic period.

The next highest group—the Amphibians—appeared later than the fishes, in the Carboniferous, which followed the Devonian. In the next epoch, the Permian, the first reptiles appear. In the Jurassic come the first birds. We now reach the Mesozoic or middle age of organic life. Mammals, which are the highest group of Vertebrates, are older than the birds; they first appear in the Trias, the period preceding the Jurassic.

The history of plants also suggests progress; the oldest known forms are algae. These were followed by Cryptogams (e.g. Ferns), these by Cycads and Conifers, and these in turn by the Phanerogams or flowering plants. This sequence accords with the systematic position accorded to the various groups. Yet there are numerous exceptions. The Liverworts, a lowly group, are not known from the woods of the Carboniferous epoch, but first appear in the Tertiary strata. Mosses first appear in the middle of the Mesozoic period, and they occur in large numbers in the Tertiary.

The whole question of progress in the organic world is thus of extreme complexity.

§ 2. *Palaeontology and Darwinism.*

The science of palaeontology owes its origin to Cuvier; to him we owe the two suggestions: firstly, that extinct animals do not belong to the same species as living animals, and secondly, that there is a distribution in time of organic forms. He also originated the hypothesis that there has been progress in the world of living organisms. But he was much influenced by the story of the Deluge. He held that all the 'catastrophes' that he postulated had occurred within a comparatively short space of time; that man had been in existence before them, living in some unknown corner of the world—a corner probably later submerged.

He also suggested that the succession of both the human and animal inhabitants in our part of the globe was due to a series of migrations into that area from the original home.

Cuvier felt that the Story of Creation did not furnish a satisfactory explanation of palaeontological facts, and he sought to overcome these difficulties by this theory of migration—a theory which probably did not entirely satisfy its formulator. His successors accepted his theories without having followed their growth; hence they were unaware of the emptiness of the word 'Creation' as he used it. Many of them, as for instance d'Orbigny and Agassiz, did not find any difficulty in assuming that there had been a sudden new creation *en bloc* after each catastrophe!

Bronn, the German palaeontologist, had successfully attacked this idea before Darwin's time. He had demonstrated that some fossils continue from one formation to another, while there is a continual dying out of old forms and a creation of new ones as we follow the fossil remains from stratum to stratum. But few dared ask how the creation of these various forms of life, or of the whole living Universe, came about. They felt that human understanding was powerless to attempt an explanation—too much was known of Nature's impenetrable mystery and of her infinite power.

Then came Darwin. Adopting Lyell's theory of gradual changes in the earth's crust, he taught that life has continued since its beginning in one unbroken stream, and that the origin of new forms and extinction of old ones can be explained without invoking any factors which surpass human understanding. Many of the palaeontologists of the time regarded the theory almost as a personal insult! In no branch of science was it given a cooler reception. They had declared that the problem of the origin of new forms was wrapped in absolute mystery. Darwin affirmed that English cattle-breeders had long ago found out how new species can be obtained. Nature, in producing new forms, follows the methods that are

used in England for breeding sheep![1] The theory was rejected by de Beaumont, Barrande, Pictet, Fraas, Heer, Bronn, Giebel, Waagen, Fuchs, d'Archiac, Owen, and Forbes. They were not all against the suggestion that one form may possibly be transformed into another; but they objected to Darwin's interpretation of the causes which lead to the origin of new species.

The following objections to Darwin's theory are the most important that were brought against it by palaeontologists.

(*a*) In the history of the earth we do not find a regular, continuous, and progressive series of changes leading to the transformation of organisms. There have been rather periodically recurring transformations; long periods of comparative stagnation have alternated with shorter periods of change.

(*b*) We come to certain times when the majority of the existing forms suddenly disappear. These are replaced just as suddenly by a new fauna. The members of this fauna are not directly related to their predecessors. One form is substituted for another, not transformed into another.

(*c*) Extinct forms do not bridge the gaps in the series of living forms; they are not truly transitional. The series of animal forms, however far we follow it back, does not narrow down to some single type hidden in some primitive rock. For the most part the extinct forms merely make the series of existing forms more complete, even as the American fauna supplements the European.

(*d*) Since the Deluge, all species have remained constant; no new ones have been created.

(*e*) Darwin underestimated the completeness of the geological record.

How could we distinguish between palaeontological genera and species if he were right in assuming that only a small portion of the continuous stream of living organisms has been preserved by chance from a continual

[1] This sense of insult is very clearly seen in d'Archiacs *Kritik der Darwinischen Theorie.*

series? Do we not in fact find hundreds or thousands of one and the same form in any fossiliferous layer?

These objections were soon satisfactorily answered by the Darwinists, and henceforth Darwinism dominated palaeontology, as it dominated so many branches of science.

Darwin was convinced that history does not represent an evolution of ideas, but merely a succession of material bodies. Applying this thought to palaeontology, he regarded it as the study of the continuous succession of separate plant and animal bodies. It is as if an historian omitted from his story any account, let us say, of Greek culture, of Roman republicanism, or of the Wandering of the Nations, disregarding these as mere empty ideaology; and as if he wrote a history of Man, in which all that was stressed was where each individual was born, how long he lived, and how many children he had! The Darwinians see reptiles predominant in Mesozoic times, and replaced by mammals in the Tertiary. They take each separate type of reptile, each type of mammal, and seek its ancestral form. The aim of every inquiry is the construction of a genealogical tree, and anatomical characters are relied upon for these trees. It is therefore easy to understand why the Darwinian palaeontologists have laid so much stress on the incompleteness of the record.

'If we knew all the extinct Floras and Faunas, the evolution of the organic world would be clearly revealed to us.' Variations of this theme are to be found in the writings of most palaeontologists—in those of Darwin, Steinmann, Zittel, Neumayer, and many others.

Historians do not speak thus. They do, of course, complain of the deficiency of the documentary record, but there is no desire to lay too much stress upon such deficiencies. The documents are regarded as so much evidence; historians examine them carefully and so increase our knowledge of the past. The palaeontologist, however, does not discuss the record; he does not regard it as 'documentary' in the historian's sense. His records are actual bits of that history; hence the palaeontologist does

not make any distinction between the actual history and the scientific study of that history.

There are various palaeontological series which have become extremely important, and which, by reason of their supposed completeness, are never omitted from any book devoted to Darwinism—those, for example, which illustrate the evolution of the horse, of the Ammonites, and of various snails. These have undergone very drastic criticism at the hands of Fleischmann.[1] This criticism has not been refuted, and the drift of it is easily understood. We have no idea how one form is changed into another; whether according to Darwin's rule of gradual evolution, or, as Cope has suggested, by a change in the characteristics, now of the species, now of genus, at another time of the order. How then can a genealogical tree lay claim to any sort of accuracy? it is based merely on the similarity between certain bones! We must, in the end, ask ourselves, what is gained even if we *are* able to prove the correctness of these genealogical trees? Has palaeontology no higher aim than to try to discover from which kind of animal each organism is descended?

Darwinism was lauded as having thrown a new philosophical light upon biology. Yet it would be a mistake to suppose that the science was absolutely changed by this innovation. Morphology, embryology, palaeontology, systematic biology—all those fields, in short, which were the first to be affected by the revolution, have remained the same dry classificatory text-book sciences as they were formerly.

Palaeontology is a great offender in this respect. It professes to tell us the *history* of organic life—history, *vitae magistra*, a subject with innumerable appeals to the imagination and the aspirations of mankind! Palaeontology commands the same weapons. She deals in millions of years. Enormous catastrophes reveal themselves. The traces of remarkable floras and faunas are discovered. Who can remain unmoved as these are unveiled? Yet a book

[1] A. Fleischmann, *Die Deszendenztheorie*, &c., 1901.

on palaeontology contains little but empty classification, soul-deadening genealogical trees concerning animals with strange names—which indicate here a tooth, there a bone; while relegated to the introduction or to the final chapter there will be a few words of praise or criticism of Darwin's theory of natural selection.

To what end did such animals ever exist? What did they look like? What sort of lives did they lead? Why did they become extinct? What is the meaning, for example, of the replacing of the dominant tree-like Cryptogams by the Phanerogams? Palaeontology gives no answer. Instead of being the leading biological science, she is as cold and lifeless as the stones which she piles up in our museums.

Steinmann seems to have realized this and complained that palaeontology has no method of its own. He holds that it must emancipate itself from the merely classificatory, and reforming itself, adopt the method of the historian. If the historical relationships between animals are kept well in mind there will be less need for the palaeontologist to turn his attention to questions of anatomical relationship.[1] He will not conclude, because of the resemblance between them, that mammals are all descended from some primitive mammal. From the fact that, in the tertiary epoch, mammals replaced the mesozoic reptiles, he, as palaeontologist and historical writer, will conclude that the mammals are the descendants of the reptiles—that, in fact, certain groups of mammals are descended from certain definite reptilian groups—that the Icthyosauri were replaced by dolphins, the Plesiosauri by sperm whales, the Thalattosauri by the whales. He will reject the prevailing theory that Trilobites became extinct at the end of the palaeozoic period, and will show how they were transformed into the Isopoda (e.g. the Woodlouse), into Decapoda and Cirripedes, into Spiders, Insects, and Fishes.

It is quite possible that Steinmann did not pay sufficient

[1] G. Steinmann, *Die geologischen Grundlagen der Abstammungslehre*, 1908.

attention to the hypotheses of Cope and Brunner. They believed that an animal can undergo a change in the features which characterize its race, its family, or its order, without undergoing a simultaneous alteration in its specific characters.

The greatest objection to Steinmann's work is that he merely substituted another series of eventualities for those suggested by Darwin. Is it necessary for the palaeontologist to believe that the mammals of the tertiary period represent the very much transformed descendants of mesozoic reptiles, before he can discuss their succession? Must the historical writer know from which of the subjects of the French king Marat, Danton, and other leaders of the Revolution were descended before he can report upon that Revolution?

§ 3. *The Reaction against Darwinism.*

The Darwinian theories never became absolutely predominant in palaeontology. Many famous palaeontologists sided with Darwin. Among them were von Zittel in Germany, Gaudry in France, Neumayer in Austria, Marsh in America, Huxley in England, Kovalevsky in Russia. Nevertheless there were always the dissidents to whom Darwin's ideas were inacceptable, e.g. von Ettinghausen and Cope, who developed views which were, from the very beginning, absolutely unorthodox.

In 1867 Waagen of Vienna made a distinction between variations and mutations. The first term he took to denote variations in the members of species belonging to the same geological epoch—this would include, for example, the variations among the individuals of any existing species. Mutations, on the other hand, were to include those gradual changes—presumably always proceeding in the same direction—which a form may undergo in the course of several geological epochs.

Neumayer, who was also working in Vienna, made an exhaustive study of molluscs which gave much support

to this view. Neumayer first believed that these ideas of variation and mutation would fit into the Darwinian frame. When they were further investigated they led to a new conception of a species. Mutations were studied in a great variety of forms and many tables were constructed. These differ from phylogenetic trees in that they contain no hypothetical forms. Further, they take into account the similarity of the whole body, and not of isolated organs. Lastly, they generally run in parallel columns, without branching. We may give the following table, which illustrates the palaeontological evolution of the Proboscidia, as an example of this type of work.[1]

		MASTODONS.		ELEPHANTS.	
Period.	*Dinotherium.*	*Molar teeth with conical tubercles.*	*Molar teeth with transverse crests.*	*Molar teeth with parallel lamellae.*	*Molar teeth with rhomboid lamellae.*
Present-day Quaternary times.			M. americanus.	E. indicus. E. antiquus.	E. africanus. E. priscus.
Upper Pliocene.		M. arvernensis.	M. Borsoni.		
Lower Pliocene.		M. arvernensis.	M. Borsoni.		
Upper Miocene.	D. giganteum and gigantissimum.	M. longirostris.	M. turicensis.		
Middle Miocene.	D. laevius.	M. augustidens.	M. turicensis.		
Lower Miocene.	D. Cuvieri.	M. augustidens, var. pygmaeus.	M. turicensis.		
Oligocene.		Palaeomastodon Beadnelli.			

According to this table the mastodons fall into two series: those which lie next to each other across the table (e.g. *M. arvernensis* and *M. Borsoni*, or *M. longirostris* and *M. turicensis*) are related as species of the same genus; those which follow each other down the table represent mutations in a succession of forms.

[1] Ch. Depéret, *Les transformations du monde animal*, 1907.

These chronological series represent a new departure in systematic biology—they can only be defined historically. The genus represents an ideal abstraction from many similar species. The series (Depéret calls it a *phylum*) is connected in a quite definite manner with some definite epoch of the world's history, and its members must be ordered in one definite sequence. Many of these series show evolution according to definite laws inherent in the organism. They demonstrate the continued differentiation of certain structures, an increase in the size of the body, and often recognizable periods of youth, maturity, and decline. The extinction of an organism reveals itself as due to internal causes.

This idea of series is sometimes extended to larger groups of organisms. The Ammonoid forms Goniatiideae, Ceratitidae, and Ammonitidae were formerly grouped as families, each one, it was thought, having been evolved from some original stock. Now they are regarded as merely developmental stages in the whole Ammonoid series; this contains a very great variety of forms, which represent varying levels in an evolutionary series which is advancing along several parallel lines.

Although these tables introduce a new idea, and replace the older genealogical trees, nevertheless they are nothing but a concrete expression of Darwinian ideals—of the endeavour to replace the ideas of systematic biology by the idea of an historical series. The hypothesis upon which all such series are based, is the old one—that each mutation has been gradually evolved from its predecessor. This in itself is enough to indicate the source from which all such work has sprung.

XIX

NATURAL SELECTION

WHEN he is considering natural selection Darwin speaks of Nature almost as if she were alive:

'We behold the face of nature with gladness, we often see superabundance of food; we do not see or we forget that the birds which are idly singing round us mostly live on insects or seeds and are thus constantly destroying life; or we forget how largely these songsters, or their eggs, or their nestlings, are destroyed by birds and beasts of prey; we do not always bear in mind that, though food may now be superabundant, it is not so at all seasons of each recurring year' (*Origin of Species*).

Darwin was here merely following the lead of contemporary political economists, and applying their ideas in the world of science. He showed one factor at work—a struggle. He interprets this as the force *par excellence* which causes evolution, and then considers how this force works, in conjunction with variation, heredity, correlation, &c. Given Nature, and the constant struggle for existence —this struggle, if there is variation too, will result in the survival of the fittest.

This word 'result' has a double meaning. It is used first of all to denote those objective realities which succeed one another in time (*after* the struggle for existence comes the survival of the fittest). It also denotes a logical deduction (if we consider the struggle for existence, we *must* arrive at the idea of the survival). All through Darwinism this logical peculiarity recurs; each idea denotes both a logical abstraction and an actual object or event. It is impossible to misinterpret such words as 'Zoology' and 'the Animal World', to confuse science with the objects of science. But such words as Phylogeny, Ontogeny, are used by Darwinists to denote both a science and its object. So *natural selection* denotes both an idea and an event.

We 'explain' phenomena either by showing what has caused them, or by demonstrating the reason for their existence. We do the latter when we show why a certain thing *must* be as we find it, and not otherwise, why, for example, the sum of the angles of a triangle must be equal to 180°. Our explanation is referred to causes, when we show what has produced an event; for example, the cause of a musical note is a vibrating string. (In addition to all this, teleological and moral explanations exist, which we are not considering here.) 'Natural Selection' is used at one and the same time to express both an objective cause and a subjective reason—it is meant to be interpreted thus. Actually it only denotes a subjective reason—for we cannot see it active and at work in Nature. Darwin does not cite one case where natural selection is actually taking place; and when he speaks of it, he generally begins with such words as 'Let us assume that—'

This peculiarity of Darwinism, which differentiates it from all other scientific theories, was soon pointed out by its opponents. The Duke of Argyll called it 'abstraction personified', but as it is no real abstraction from separate phenomena, it would perhaps be better described as 'deduction personified'.

Darwinists never free themselves from these difficulties. They continually assert that natural selection can produce nothing new—and yet are constantly forced to assume that it has been the cause of differences in structure. They recognize that we cannot study natural selection in actual operation. 'The saddest thing of all', said Weismann, 'is that, in scarcely one case, can we say whether a certain deviation is useful or not; there seems no prospect of our ever being able to do so.' Recently Plate has spoken in almost the same words:[1] 'It is practically impossible to estimate the value, for purposes of selection, of any single object; often we cannot even tell whether an apparently useful organ is worthy of selection or no. From

[1] L. Plate, *Selektionsprinzip und Probleme der Artbildung. Ein Handbuch des Darwinismus*, 1908.

this we see that the theory of selection is not one whose validity can be tested by the examination of isolated instances; but it is a logical deduction from such general facts of experience as variation, overpopulation, and the struggle for existence.'

A further peculiarity of the theory is that it looks upon progress as a purely passive thing. By *life* Man has always meant an activity, a development of power, an effect upon the surroundings. Progress in the world was believed to depend upon endeavour, upon the struggle for ideals, upon the force of the individual, and we are as a matter of fact still convinced that this is so. Indirectly, Darwin opposed this idea. Life itself can do nothing; according to him it is only a plaything in the hands of the most diverse external factors. There is no stepping forward, one is only pushed forward. If a man has some advantage over others he cannot develop it and make it of value by his own efforts; and at his death all that he has struggled for dies too. The only individual who can hope for victory is the one who produces a numerous progeny—that is the teaching of the selection theory.

We cannot give the history of the development of this idea of natural selection, for there has been no development; the idea is an abstract one, and means to-day just what it meant in Darwin's time. We shall find this all the more striking when we remember that this idea of selection has always been the central idea round which discussion has ranged.

There is no doubt that the conditions under which animals live are altering before our eyes. In Scotland the song-thrush is being ousted by the missel-thrush. In Australia our bees are gradually replacing the native stingless bee. Round us the little singing bird *Serinus hortulanus* is constantly appearing—formerly it was never seen here (i.e. in South Germany).

But what is the nature of the struggle that leads in the one case to victory, in the other to destruction? Of that we know very little.

An extraordinary light is thrown on the anthropomorphic views of the nineteenth century by the ideas about artificial selection which were then held. Without any experimental proof whatever, Darwin claimed that Nature follows essentially the same methods as does Man, when he wishes to produce a new race.

A few of the older critics challenged this assertion, and demanded its foundation. Even now investigators do not seem to realize how such a statement cries out for proof.

XX

CARL VON NÄGELI

CARL NÄGELI, the well-known German botanist (1817–91), was a scientist with an established reputation when Darwin published his theory. He had done a considerable amount of work on Schleiden's cell-theory and on minute anatomy, and was well known as one of the early supporters of the new materialistic views. He knew the attractions of the *Naturphilosophie*, and enthusiasm for Oken's idealism had induced him to forsake medicine for botany. He had gained an insight into Hegelian ideas from Hegel's own lectures; indeed, Nägeli was accused by Schleiden of being nothing but a follower of Hegel. Influenced by the materialism of the day, he had abandoned the idealistic standpoint, and when Darwin appeared Nägeli was prepared to welcome him. But no enthusiasm for the new ideas could quite destroy the influence of those youthful ideals.

In 1884 Nägeli published a book on the evolution of the living world, which bore the bold title of *A Mechanico-physiological Theory of Evolution*. It dealt very fully with the phylogeny of plants, and contained in addition a considerable amount of scientific materialism, including theories of the origin of the atom, and concerning molecular forces. Nevertheless, he ends by claiming that Darwin paid too little attention to the whole organization of the body, and he asserts that some force tending towards perfection must be the still deeper principle which underlies natural selection. He agrees with the older morphologists in distinguishing between the original plan and the adaptive characters of a plant. The plan makes the rose a member of the Rosaceae, the mistletoe of the Loranthaceae, the tulip a monocotyledonous plant; adaptation is exhibited in the colour of the rose and the peculiar

suckers of the mistletoe, for the environment has stamped these characters on them.

According to Nägeli, life, once formed from lifeless matters, contained an urge driving it towards ever higher forms—towards perfection; even as the forces within the solar system have driven the whole system since the beginning of time. He believed that, as the result of the interplay of chemical and physical forces, simple cells are constantly being formed from lifeless matter; that their powers of growth, reproduction, inheritance, and variability follow from the mechanical structure of this living substance; and that evolution to a high form must follow as the result of the possession of these powers.

Man is ultimately descended from the oldest formed cells, the monkey from somewhat younger cells, the modern infusoria have arisen quite recently. Hence modern monkeys are not the descendants of those of the tertiary period; they have been evolved from lower forms, and their descendants will in time become human. But by that time present-day humanity will have advanced further. The world of plants and animals thus resembles a garden containing many branching trees; these constantly produce new shoots, which represent the fauna and flora of to-day; they grow, driven by an inner urge and pruned by natural selection. If there were no struggle for existence an enormous number of forms would arise, which would interfere with one another. As the gardener prunes away certain branches, thus preventing his bushes from growing into shapeless and tangled masses, so natural selection kills off those forms which are not following the predominating line of evolution.

It is easy to see traces of vitalistic ideas behind Nägeli's theories. He invented the idea of invisible living units —*Mizellen.* He was so sure of their existence that he could estimate their size. They have a volume equal to one three-millionth part of a cubic centimetre, and a live seed contains 4,000 billion *Mizellen*; he even described their chain-like arrangement in living substance. Proto-

plasm is formed from them, and is of two kinds. One (*Idioplasm*) contains all qualities *in nuce* and 'is like a microscopic picture of the macroscopic individual'. The other (*Stereoplasm*) is different in different parts of the body, and each sample contains only certain of the qualities which characterize the individual to which it belongs. Nägeli cited laws which he believed to underlie evolution, driving it along its appointed road.

(*a*) The law of phylogenetic union. Following this law unicellular organisms divide and become multicellular.

(*b*) The law of complexity, differentiation, and reduction. Similar cells become differentiated and form tissues; at the same time, the development of the individual organism is simplified, certain steps of its phylogenetic evolution being omitted.

(*c*) The law of adaptation to the environment.

Nägeli's attempt to introduce the principle of 'an evolution towards perfection' into biological theory, and to drive natural selection into a position of secondary importance, was not favourably received. His mechanistic views were ignored by Darwin and his school and they accused him of mysticism; others—like Wigand—who understood these 'mystical' ideas drawn from an earlier view of morphology, accused him of materialism.

Nägeli himself found it difficult to reconcile his idea of organic continuity with the fact of the constancy of species; yet he fully believed in this constancy, and cited it against the Darwinian theory. In spite of all these difficulties, biological thought was strongly influenced by Nägeli; notably many thinkers endorsed the opinion that some deeper principle than Natural Selection must be found to account for evolution.

Weismann adopted Nägeli's view of two kinds of protoplasm when formulating his theory of heredity and the germplasm. Askenasy accepted the principle of perfectibility.[1]

Von Sachs' work is transitional between the Darwinian

[1] E. Askenasy, *Beiträge zur Kritik der Darwinischen Lehre*, 1872.

and post-Darwinian epochs. He owes much to Nägeli. He is in favour of the mechanistic view; believes that the study of phylogeny is the highest goal of science, and that through it the idealistic (or, as he calls it, the 'scholastic' morphology) will be discredited. He distinguishes between those characters (organic) due to a formative force and those others (adaptive) due to reaction with the environment. Certain views expressed by De Vries concerning 'elementary' species, and the differences between inheritable variations and non-inheritable fluctuations, are also founded on Nägeli's views.

Nägeli was the first important scientist who, relying solely on intellectual arguments, nevertheless rejected empiricism, and with him began the reaction against it. He says very definitely that he offers his rationalistic theory, which is purely German in origin, in place of the English work, which is nothing but a mere collection of facts. In those days it seemed strange to contrast the two in this way; yet here was a suggestion which was destined to be much more fully developed.

XXI

THE CELL THEORY AFTER THE TIME OF DARWIN

§ 1. *Development of Cell Theory.*

WE have already pointed out the difference between the old and the new biology—the one idealistic, the other naturalistic. The cell theory underwent a similar change. When Schleiden and Schwann discovered that a body is composed of innumerable cells, they struck a blow at any idea of the 'unity' of the whole organism. The cell became the unit. Virchow went even further, and developed his idea of a cell republic. He taught that disease does not attack the whole organism, but that it is localized in certain groups of cells. The cell became for biochemistry and biophysics what the atom is for chemistry; general ideas were abandoned. The cell was used to 'explain' everything—inheritance, variation, the processes of life, the nature of sex, even the soul and immaterial phenomena.

Many biologists, even to-day, believe that all the problems of the living body can be reduced to problems of the single cell. Hertwig, for example, having published his work, *Cells and Tissues* ('Zelle und Gewebe'), gave to later editions the title *General Biology* ('Allgemeine Biologie'). In accordance with the usual scientific tendency of the times, the cell-theory when first formulated was accepted by all workers as a dogma. No attempt was made to investigate the nature of the cell or its relation to the whole organism. From 1840 until the end of the century we may search the records in vain for any worker who believed in any theory in place of the cell-theory.

The great histologists of the time—Virchow, Kölliker, Strasburger, &c.,—accepted Schleiden's vague and sketchy views, and made it their task 'to find out of what elements those cell structures, which still seem to us simple, are composed', as Kölliker expressed it. Research was focused

upon the protoplasm and the nucleus, and an elaborate microscopic technique was evolved, for which very careful and laborious methods of staining were required.

We will pass in review a few of the more general constituents of the cell, and then summarize the theories propounded concerning them.

The cell may assume many forms. Some have a volume of several cubic centimetres (e.g. the egg-cell of the bird); some are so small as to be invisible with any microscope (e.g. some bacteria). Cells may be spherical, thread-like, plate-like, branched, &c. Driesch has pointed out that in any given organ the size and form of the cells composing any one of its elements remains constant. Others have asserted that the size of the cells in any given tissue element varies round a definite mean. Cells may possess certain organs—cilia and flagella—by means of which they move; coloured eye-spots, by which they see; a cell-mouth, for the absorption of nutriment; fine muscle fibres, &c. Those cells which form part of a tissue are, however, usually simpler in structure.

Plant cells consist as a rule of the following parts: Firstly, a tough membrane, the cell-wall, which consists of a substance chemically related to starch. Secondly and within this, a colourless, semi-fluid substance—the protoplasm. This lines the wall, and stretches out as threads which unite it with a denser mass of the same substance—the nucleus. Thirdly, vacuoles, filled with a watery fluid containing various substances in solution. The protoplasm is a colourless, homogeneous ground substance, containing numerous very small bodies—the microsomes.

Plant protoplasm often contains larger bodies—leucoplasts—which form starch, and green chlorophyll bodies—chloroplasts—to which the green colour of the plant is due. Plant protoplasm appears to be in continual motion while alive. It always contains a nucleus, generally oval in shape, which is in its turn made up of various components. One of these can be easily stained and is called

chromatin. The living cell absorbs the raw materials and energy which it needs, and produces the substances upon which it lives; it can grow, and, when free, can change its shape; it is irritable, and can reproduce itself.

The phenomena accompanying cell division have been much studied. Since Virchow's time it has been generally admitted that new cells can only be formed by the division of pre-existing ones. The chromatin of the nucleus at first collects into chromatin granules—these group themselves as threads, and these then collect into a ball. At each of the two 'poles' of the nucleus a small body appears —the centrosome; the two centrosomes mark the points where the new nuclei which will arise from the old one will appear. The threads of the ball now look like horseshoe-shaped loops (chromosomes); these are grouped in the equatorial plane midway between the two centrosomes. The chromosomes can now be counted, and each type of animal and plant possesses a definite number of chromosomes.[1] The smallest number known is two—yet 168 or even more occur in some cases. The relation, if there is any, between the number of chromosomes and the other characteristics of an organism, is quite unknown.

Each chromosome now divides lengthways into two; one half moves towards the one centrosome, the other towards the other. All the chromosomes at each pole collect and form a tangled lump in this position. Then they return to the state of chromatin granules, and so finally form a new nucleus.

Meanwhile the protoplasm itself also divides by simple constriction into two parts, and so, from the 'mother' cell, two 'daughter' cells arise. They may separate and live as single cells (in unicellular forms), or they may remain connected, taking on various forms and functions, and so forming part of a tissue.

In recent years so much work on the cell has been done, so many theories have been suggested, so many new terms have been introduced, covering so many newly found

[1] Yet many exceptions to this rule are known.

structures and raising such special problems, that a reader of histological and cytological literature becomes very confused.

It is as if the clue to all living problems were hidden in the cell, as if the microscope could disclose to us all the unknown springs of 'being'. This fashion is, however, already on the wane, and in a few decades the historical writer will find it difficult to wade through the extremely complicated terminology that has been introduced. His task will be a dull one, since the only interest that will then remain will be archaeological. Nevertheless, the influence of this cell-theory on other departments of biology must now be discussed.

§ 2. *Embryology and the Cell Theory.*

The fact that every organism begins as a single cell, and that development is always accompanied by cell-division, added to the prestige of the cell theory. Every fact connected with cell-division was believed to have embryological significance. The method of segmentation of the egg was thought to be particularly important, and the different types of segmentation were used to subdivide the whole animal kingdom. These differences were later shown to be of secondary importance.

The following types were distinguished:

(*a*) Complete segmentation, when the whole egg divides into two cells, into four, and so on. Division may be equal, when the daughter cells are of the same size; or unequal, when they differ in size.

(*b*) Partial or incomplete segmentation. The egg here divides into two cells, of which the one, the greater, contains a great deal of yolk and little protoplasm; the other, the less, chiefly protoplasm. The second smaller cell undergoes further division. Here the segmentation may be 'discoidal', when the division is confined to a small plate of cells at one end—the so-called animal pole—of the egg; or 'superficial', when the surface of the egg undergoes

segmentation, the yolk remaining in the centre and taking no part in the division.

Kölliker therefore divided animals into those in which the segmentation is complete (vertebrates, anthropods, gastropods, cephalopods), and those in which it is partial (worms, jellyfish, polyps, medusae). Van Beneden (1874) and Jäger (1870) worked out similar classifications.

The cell theory had considerable influence upon ideas about the nature of embryonic development. Since all the cells of the mature organism arise by repeated division and differentiation, it seemed as if it would be particularly useful to follow the development of each type of cell during the embryonic stages of growth. It was found that certain parts of the body, e.g. the epidermis, the sex cells, the innermost layer of the digestive tract, arise by continued division from definite embryonic cells. Attempts were therefore made to follow the origin of all the elements of the body back as far as possible.

Sometimes these efforts were crowned with success. Boveri traced the origin of the sexual cells in the threadworm of the horse to the four-celled stage of the blastula. One cell of the four-celled embryo gives rise, by repeated division, to the reproductive cells of the adult. In cyclops—an arthropod—the sex cells develop from one cell of the thirty-two-celled embryo. It was further found that when the segmentation is unequal, the smaller cells form the ectoderm, the larger the endoderm. In other cases the results obtained were not so simple. The muscular system, for example, which is so uniform in the adult animal, is sometimes formed from ectodermal cells, sometimes from endodermal, usually from the mesoderm. The true nerve cells arise from the ectoderm, the cells of the neurilemna, which are scattered among them, from the mesoderm. In these cases the developmental history seems of minor importance; in the one case the same tissue is seen to arise from cells believed to be absolutely independent, while in the other case elements which form a uniform whole in the adult arise from two types of embryonic cell. These facts

tended to lessen the importance attached to the view that the history of individual cells is of absolutely fundamental significance in embryology; but it did not destroy it altogether.

The task of following the history of the millions of cells, which become connected, divide, and move in a most complicated way, was seen to be a difficult one, but it was not abandoned, for it was believed that every cell in its normal development underwent a definite series of changes, and that these had been fixed by millions of years of heredity.

It was the study of the phenomena of regeneration that finally overthrew the belief in the importance of the cell theory for embryology. In some worms, for example, mesoderm cells were shown to be regenerated from ectoderm cells; and in general the fate of cells in regenerative processes is quite different from their fate in the normal course of development.

§ 3. *The Neuron Theory.*

In the early nineteenth century the vitalistic theory was still predominant; a living principle was believed to dwell somewhere within each body, and to regulate all its activities. Bichat did not agree with this. He taught that for each tissue within the body there exists a separate vital principle. The cell theory brought with it the assumption that each cell of the body is a separate centre of activity. Virchow believed this implicitly, and adapted the idea to make it fit into his theory of the nervous system; he held that there is no soul controlling the whole body, but that each nerve cell represents a separate centre of nervous control.

Towards the end of the century it seemed as if this idea was to receive strong confirmation. Earlier hypotheses as to the minute structure of the nervous system did not correspond well with Virchow's views. It was thought at that time—Gerlach's name is particularly connected with

these ideas—that the whole nervous system consisted of nerve cells and their thread-like branches. These ramify in all directions, and then unite to form a network spread over the whole body, and particularly over the central nervous system. In the 'nineties, however, the Spanish histologist, Cajal, occupied himself with demonstrating that no such Gerlach network exists, but that the branches from each nerve cell remain quite separate. Their branches, he held, come into close contact with the branches from other cells, but never actually unite with them. This view was ultimately accepted by most histologists, including Kölliker. Waldeyer gave the name *neuron* to a nerve cell with all its branches, and hence the term *neuron theory*.

This assumed that there are as many separate centres of nervous activity as there are nerve cells. Each cell lives its own individual life. Branches, at their points of contact, pass on a stimulus from one nerve cell to another—and so a stimulus is conducted. Nerve cells only differ from one another in size, in the number and direction of their branches, and in other similar material points of structure. Particular importance was attached to the fact that no differences in the nerve cells could be demonstrated which correspond to the obvious and striking differences between psychological processes.

The nervous system is only an aggregate of nerve cells. These have physiologically different functions; one, somehow or the other, produces the sensation of redness, another of yellowness, others give the memory for words, &c. The most distinguished histologists accepted this theory. Physiologists like Helmholtz endeavoured to make their views harmonize with it. The psychologist Wundt raised no objection to it; he found it capable of explaining certain of his difficulties.

Nevertheless the theory was incorrect; the Hungarian histologist Apâthy and the German psychologist Bethe were later able to show conclusively that Gerlach's idea of a network was more correct than is this idea of the neuron. Just as, formerly, the correctness of the neuron theory had

been widely assumed, so now its incorrectness was demonstrated by many workers; to-day it interests us solely because it is so very characteristic of the thought of the nineteenth century.[1]

Some Theories Relating to Structures which are Smaller than Cells.

Every object of thought can be resolved into its 'elements' in two very different ways, according as these 'elements' differ from the whole object quantitatively or qualitatively.

We can resolve the state into human beings, human beings into organs, the organs into tissues, tissues into cells, these into chemical compounds, into molecules, atoms, and so on; or we can resolve human beings into body and soul, these into their separate sensations, and so on.

Analysis according to facts of time and space is purely quantitative.

A body occupies a definite space and lives for a definite time. We can think of it as divided into elements which occupy a certain space, say 1 ccm. or 1 mm., and which live for a certain time—an hour, a minute, or a second. However little we may know about the internal structure of the human body—this we can assert *a priori*; that there is no final unit of time or space into which that body can be subdivided. Philosophers have often dwelt on this theme.

The analysis of the human being into qualitatively different elements—into soul and body, into organs and tissues—bears no relation to quantitive analyses. Without our own subjective experience, the knowledge that each man thinks and feels much as we do, that he reveals a soul, we could not arrive at any such qualitative subdivision by considering the material facts of our existence.

In the same way the fact that the body consists of

[1] A fuller account of the neuron theory will be found in Kölliker's *Handbuch der Gewebelehre*, edition 1896. This also gives a full list of references to the literature of the subject.

tissues had first to be discovered. He who has not seen the cells of the human body could not guess at their existence. Similarly, we might by chance guess that the air consists of small particles; but no guess would suggest that it consists of oxygen and nitrogen. This fact had to be discovered.

The men working out the cell theory were victims of the general human desire to substitute logical analysis for analysis of the actual facts of experience. Leibnitz, Buffon, Haller, Milne-Edwards, Oken had taught that the body is made up of minute invisible spheres, grains, fibrils and the like. Soon after the discovery that these ideas were false, and that it is composed of cells, workers fell into the same mistake again; and they now looked for these ultimate spatial elements within the single cells. The materialistic tendencies of the times, together with the importance attached to microscopic work, encouraged the growth of this mode of thought.

Darwin indulged in this type of speculation. In order to make the mechanism of inheritance clear, he postulated that there are in the body minute invisible particles which are the carriers of hereditary qualities. These circulate freely in the body, collect in the reproductive cells, and so are passed on to the next generation. When the egg segments, these particles also divide, pass into the newly formed cells, and, arriving at definite positions in the developing organism, call forth there the properties which they have carried hidden within them.

To understand how Darwin came to postulate such a theory (which did not differ from those of the eighteenth century or for that matter from those of Aristotle), we must remember that he had no practical experience of the cell theory or of histological work. His contemporaries who had such knowledge received the theory unfavourably; Huxley did not accept it, nor did Weismann, nor even Haeckel. It was not, however, his attempt to subdivide the body into minute spatial elements that roused their opposition, but rather the picture that he gave of the

circulation of these elements through the body when there was no known apparatus to render this possible.

The belief that the cell contains definite properties, carried by definite material particles, was accepted, and formed an important part of the theory of evolution; Darwin called these particles *gemmules* (1868); Elsberg (1870) and Haeckel (1876) called them *plastidules*; Herbert Spencer *physiological units*; De Vries (1889) *pangenes*. Francis Galton (1876) called them *stirps*. Weismann (1885) suggested that there is a whole series of them.

Other writers were less concerned with heredity; their endeavour was simply to subdivide the organism into particles smaller than cells. Brücke (1861) was among these. He suggested that the cell consists of 'elementary particles'; Nägeli (1884), Weisner (1892), O. Hertwig (1906), and Altmann (1890) discussed these under various names.

Other workers thought it better to postulate certain physical structures and processes in the cell. Berthold (1877) likened protoplasm to a mixture of different liquids. Verworn (1901) attributed the properties of the living cell to the fluid nature of the protoplasm; Hertwig and others rejected this view, and taught that the living portions of the protoplasm are solid aggregates. Haacke (1893) suggested that protoplasm consists of minute crystals. Bütschli's (1892) foam theory of the protoplasm was very widely accepted; Flemming (1882) believed that it consists of fine threads. Many other similar hypotheses could be cited.

Every granule found in a cell was invested with the dignity of being the 'fundamental unit' of life. Special importance was attached to the chromatin and to the chromosomes formed from this. This arose from the fact that these elements are conspicuous in all dividing cells, that during cell-division they behave in a peculiar manner, and that at fertilization paternal and maternal chromosomes unite. In addition, the desire was always in the minds of investigators to find some visible inheritable substance.

It came to be believed that the chromatin is the material substance connected with inheritance—that it carries inherited characters from parents to offspring. The chromosomes were called 'character bearers'. Discussion then arose as to whether all the characters of an organism are contained in each chromosome of the egg, or whether each carries one group of characters (e.g. one the ectoderm, another the nervous system, another the teeth, and so on, —Wilson, Boveri), or whether each contains all the characters of one organism—the one carrying paternal characters, a second those of the grandfather, a third those of the great-grandfather, and so on (Rabl).

In recent years the fantastic idea that we come nearer and nearer to reality, the more we magnify the structures we are observing, has lost ground. Modern experimental morphology, the mutation theory, recent work on hybridization, and other experimental lines of work have robbed microscopy of its peculiar importance.

§ 4. *Some Objections to the Cell Theory.*

The cell theory became very important, especially in histology and embryology. The great aim of every research worker was to discover from which of the embryonic layers this or that tissue arose. Some there were, however, who felt the onesidedness of this method of attack. The wing of a bird, of a butterfly, of a bat—all these have arisen from some cell; but can we arrive at a real understanding of them only by studying their cellular origin? Is each tissue really to be regarded as an independent structure, following its own individual laws?

Such were the questions which led some workers to oppose the cell theory.

Sachs, the botanist, for example, tried to work out a new analysis of the cell, instead of accepting the view that it consists of various minute, invisible structures. Some cells may contain more than one nucleus—liver cells generally have two; marrow cells and those of some

pathological structures, some fungal cells, some cells found among the lower algae, the cells of certain Radiolaria and Infusoria, contain many, and may contain over 100 nuclei. This led Sachs to suggest that a simpler unit than the cell, consisting of a nucleus and its surrounding protoplasm, is the 'living unit', out of which all organic life is formed. Kölliker (1897) agreed with this view, and the idea received a certain amount of favourable criticism. It was not widely accepted. Multi-nucleate cells were declared either to be exceptional structures, or, in certain cases, to represent an aggregate of several cells.

Heitzmann (1883) endeavoured to show that every living body—be it an amoeba or be it a human body—must be thought of as a uniform plasmatic whole, in which the living substance is spread out like a fishing-net, the knots representing cells. This attempt to substitute another view for that of the prevailing 'republic of cells' was not popular. A somewhat similar hypothesis was put forward by Pflüger, the well-known physiologist.

In botany the cell theory, however, soon lost its preeminence. In the work of Hofmeister, a contemporary of Darwin, we see a tendency to study the plant body as a unit, rather than to emphasize its separate parts. Sachs expressed this idea clearly when he discussed plant growth. He thought that growth, with the changes in form that accompany growth, is to be regarded as the primary phenomenon, and he tried to show how the laws of cell-division can be deduced from those of growth.

Cell-division sometimes takes place parallel to the surface of the growing organ (periclinal), sometimes at right angles to it (anticlinal), in such a way that in growing organs of spherical form the anticlinal walls are generally exactly radial, the periclinals forming a series of spherical surfaces parallel to the surface of the organ. Vegetative growing points have the form of a paraboloid of rotation, and in these anticlinal and periclinal walls form parts of confocal paraboloids. Thus the arrangement of the cells in any organ can be deduced from the shape of that organ.

S. Schwendener, although his point of view was rather different from that of Sachs, yet endeavoured to show that cell-division and cell arrangements are merely due to mechanical forces which are developed during the growth of the whole body. Other botanists, e.g. De Bary and Goebel, have held similar views.

In the 'eighties, however, although such ideas were very prevalent among botanists, they found no favour with zoologists. In 1883 A. Rauber published a book on the cell, in which he gave the results of his own researches into the segmentation of the eggs of certain vertebrates; in this he tried to introduce the botanical point of view into zoology. Rauber endeavoured to show that the whole organism must determine its parts, rather than the parts —the individual cells—the whole organism. Even among animals, he pointed out, the shape of the whole body enables us to deduce the form of its various elements (e.g. the shape of the whole bone enables us to infer the form of its separate Haversian systems). The animal body is not an aggregate; it is a unified protoplasmic whole, which during its development grows and divides in definite directions, separating into definite chemical and histological units.

Rauber's work received little attention; similar ideas, however, gradually became more widespread. With the development of 'Evolutionary Mechanics', an endeavour to arrive at an experimental explanation of the shape of the animal body, the attention of the scientist was directed once more to animal form, and the cell theory—which pictured the body as a mere aggregate of cells—lost its predominance.

Roux, who began this type of work, and Driesch both pointed out that too much importance had been attached to the cell theory. Whitmann (1893) made a list of the objections to it. He showed that we lose sight of the unity revealed in each organism when we emphasize the individuality of its cells. He said that the sort of systematic zoology which is based upon the segmentation of the

egg-cell and the results of that segmentation is unnatural, since one and the same organ (e.g. the organs of excretion), may be one-celled or many-celled. The cellular nature of such organs cannot, then, be a matter of fundamental importance.

In 1894 Verworn published his *General Physiology*, containing a belated attempt to introduce the cell theory, as expressed by Schleiden, Virchow, and Haeckel, into physiology. Physiologists gave the book a cool reception. Nevertheless, even at the present day it is often considered that the problems relating to the cell, to protoplasm, to the nucleus, and to the chromosomes are the most fundamental biological problems.

XXII

HUMAN HEREDITY

FROM the earliest times heredity has been thought of as a fate which relentlessly pursues mankind.

The state of being 'born in sin' of Christian philosophy; the revenge of the God of the Old Testament 'unto the third and fourth generation'; 'Fate' which drove the heroes of Aeschylus to destruction; St. Augustine's doctrine of predestination, each man condemned to eternal happiness or eternal damnation—these all contain primitive ideas about heredity; they all suggest that the individual, although a free and conscious agent, is subject to a higher power—a power which goes back to the time when that individual was not in existence. The same thought found expression in the belief in the transmigration of souls, in the caste system, in the granting of hereditary privileges.

Darwin's theory of heredity aroused considerable discussion, but he was not the first to focus attention upon this subject. J. F. Meckel, the German anatomist, in a book on human anatomy which he published in 1812, gave a list of facts which point to the inheritance of monstrosities in certain individual families.

Before Darwin's time anatomists as a class were not, however, interested in problems of heredity. They left such work to their medical friends. In 1847 a French doctor, Lucas, published a book in two volumes which contained a mass of material—often of a very fantastic nature—relating to the inheritance of mental qualities. The book was read by the general public, as well as by the medical world.

Ten years later the French psychologist, B. A. Morel, examined in great detail the problem of the inheritance of mental disturbances. He noted that certain diseases appear in one generation after another of the same family. This led him to formulate a theory of decadence. Those

speculations which suggest that mankind will be eventually annihilated by disease are closely related to Morel's ideas. Buckle, in his *History of English Civilization*, discussed this subject of the inheritance of mental qualities, of talents, of characters both detrimental and advantageous. His final conclusion was that the subject must be left for the present; he pointed out that we must know more about non-inheritable characters before we can have any really scientific theory of heredity.

Darwin's idea of heredity differed from Morel's. The latter looked upon it as a force driving the family to a tragic end; Darwin thought of it as a conservative element, which gave historic continuity to human life.

Agassiz, Bronn, and Baer—Darwin's predecessors—believed that every species, or at least every order, had arisen independently out of the earth, and that continuity was achieved because there was continuity in the ideas they embodied. Darwin introduced his view of heredity, and succeeded in giving a purely materialistic tone to all later speculations about the history of life on our planet.

Darwin did not distinguish between different hereditary characters. He believed in the inheritance of both bodily and mental qualities, of psychological traits as well as of anatomical features, of the broad outlines and of the minute details of character, in the inheritable nature of wounds, of acquired characters, of disease, of inborn abnormalities. He quotes all sorts of examples of these events, collected from the most diverse sources. He points out how, in one family, the colour of a lock of hair was inherited; how an extremely hairy man had a daughter whose ears were hairy, and how her son developed a beard when he was only a year old.[1] He gives certain 'laws' of inheritance—among them the following:

[1] Altogether, Darwin's book *On the Variation of Animals and Plants* seems very old-fashioned to-day. This is the book in which he discussed heredity. All the weaknesses of his philosophy become very obvious in it. They are somewhat veiled in the *Origin of Species* by the abstract manner in which the problems are attacked.

(*a*) Direct inheritance implies the passing on of qualities from parents to children.

(*b*) One parent is prepotent, when the children derive more from that one parent than from the other.

Some writers believe that, as a rule, the female resembles the father more closely, the son the mother; others maintain the opposite view. Darwin himself was convinced that the qualities of the father pass chiefly to his sons, those of the mother to her daughters, and he explained the occurrence of secondary sexual characters in this way.

(*c*) The influence of time. The hereditary quality appears in both parents and offspring at the same time of life. Male birds develop their characteristic colouration at maturity, because, says Darwin, they first gained these colours at this period of life through natural selection.

(*d*) Latent qualities. Qualities, which, though present, have not yet appeared, are called latent. Sexual desire is 'latent' in the years of childhood, song is 'latent' in young birds, the characteristics of the frog are 'latent' in the tadpole.

(*e*) Sometimes qualities may remain latent throughout life. The queen bee must possess the qualities, though latent, of the drone, for drones are produced by unfertilized queens. If a child shows some character which was not possessed by its parents, but in which it resembles an uncle, grandfather, grandmother, or other more distant relative, that character must have been latent in the parent.

(*f*) Qualities possessed by descendants, but not by their immediate ancestors, are called atavistic (*atavus* = great-grandfather).

In practice we call characters atavistic when they suddenly appear in an individual or a race, and are such as might, according to our theories, have belonged to some very remote ancestor.

The domestic pigeon, for example, is probably descended from the rock pigeon, which is grey, with two dark bands on its wings. This colour sometimes appears in domestic pigeons whose parents exhibited a very different coloura-

tion. The colour and markings are then called atavistic. The horse is believed to be descended from the wild, grey horse, which has a dark stripe down its back. This dark stripe occasionally appears in young colts, and so is called atavistic. A great deal of crossing between different races is believed to favour atavism.[1]

The subject has received much attention; atavism is supposed to be exhibited even by man. Almost every monstrosity was looked upon as a 'heark back' to uncivilized man, to the monkey, or to some still more remote ancestor —e.g. extreme hairiness, development of the inter-maxillary bone, were regarded as ape-like characters; six fingered extremities were even traced back to certain marine reptiles of the Permian epoch!

From many quarters there came objections to these theories. Virchow did not deny that atavism may occur, but he pointed out that some of the cases where men have resembled animals—Theriomorphy—may be the direct result of disturbances occurring during development. He admitted that the heart may be poorly developed, that it may even resemble, in some ways, a reptilian heart; but this, he considered, is not a sign of atavism, but of mal-development.

During the Darwinian heyday, it was thought to be of the utmost importance to collect actual details which illustrated the passage of characters from parents to off-spring, as if heredity had first been discovered by Darwin! Darwin collected a mass of such material in his book on *The Variations of Animals and Plants under Domestication.*

The French psychologist Ribot, in a very uncritical book, gave examples which dealt with a rather different subject-matter.

The Swiss, de Candolle, investigated the ancestry of the members of the French Academy (1873), and as a result claimed that intellectual capacity is inheritable. Francis Galton, in England, collected a mass of statistics dealing

[1] A detailed analysis of the laws of heredity, from the old-fashioned point of view, is given by Th. Ribot, *L'hérédité*, 1873.

with heredity (1869 onwards). He maintained that size of body, skin colour, eye colour, muscular strength, intelligence, strength of will, morality, and finally, genius, are all inherited.

Variations introduce new possibilities into life—they represent a progressive element; heredity fixes—is conservative; but if it fixes acquired characters, it works for progress. Most of the biologists who agreed with Darwin —Darwin himself, Haeckel, Galton, &c., thought of heredity in this more progressive sense. Galton collected statistics to show that the inheritance of mental capacity is a factor in human progress. Darwin's doctrine, that humanity has progressed in the past and will do so in the future, was based on his conviction that spiritual, intellectual, and moral qualities are inherited.

Philosophers who were not biologists have tended to emphasize the aspects of heredity which make it seem more like a doom, causing undesirable qualities to be passed on from father to son, a doom pursuing the whole family to its final destruction. Particularly in connexion with mental diseases, sexual diseases, and drunkenness, the consequences of heredity were painted in very dark colours. Morel, to whom we have already referred, introduced this point of view. From his observations he inferred that mental disease pursues the family like a tragic fate; it passes from father to son, growing from small beginnings to a mighty destroying force, which drags the family down towards an inevitable decadence. Morel's pupils carried his theory further; they asserted that 90 per cent. of all those who develop mental disease inherit this from their ancestry—though it is not necessarily the same disease that arises.

Zola expressed this terrible view of heredity in literature. Ibsen made inherited degeneracy one of his chief dramatic themes. Writers on racial questions have tended to emphasize the same point of view and often infer that the human race is deteriorating.

Belief in these destructive forces seems now, however,

on the wane. Statistical methods are being used, and they give results that are by no means uniform; by the use of such methods there creep in certain special errors. Statistics on these matters were usually collected in asylums. If the relations of the patient had suffered from mental disease, this was taken to be a proof of inheritance; if they were free of it, a proof of non-inheritance. If we investigated poverty in the same way, taking a large number of the poor, and determining statistically in how many cases their poverty was inherited, we should get a very black view of life; but it would be an incorrect view, because it would neglect all those cases where poverty was successfully overcome. So statistics culled from asylums do not take into account the cases where mentally deranged people have healthy children—for these do not come into touch with such institutions.

Many statisticians have pointed out this fault, and, using more critical methods, have obtained less depressing results. Diem (1905), for example, is led to the following conclusions from his observations:

(*a*) If we consider the total heredity (i.e. the inheritance of all those diseases believed to be passed on from one generation to another), the burden of the sane is little less than that of the insane. In other words, the difference in health between the two sets of ancestors is hardly noticeable.

(*b*) Among the ancestors of the mentally diseased there were, however, four times as many cases of mental disease, as among the ancestors of the mentally healthy. There were also more cases of drunkenness and of certain abnormalities of character. Both sets of ancestors show about the same tendency to nervous diseases and to suicide. On the other hand, the hereditary burden of the mentally unsound is two to four times less, in regard to apoplexy and senile dementia.

(*c*) We obtain different results again, if we consider the hereditary burden due to parents only—as contrasted with that due to other relations.

The Inheritance of Acquired Characters.

Characters are either inherited or acquired; the organism brings inherited characters into the world with him—e.g. the ability to speak; acquired ones come to him during his lifetime from the outside world—e.g. the knowledge of any definite language. Recently, inherited characters have been classified; Delage, for example, differentiates between anatomical (e.g. a birthmark), physiological (e.g. duration of life), psychological (e.g. character), pathological (e.g. mental disease), teratological (e.g. supernumerary fingers), and latent characters.[1]

It is important to note that Darwin, in the *Origin of Species*, does not emphasize the difference between inherited and acquired characters. Among characters that are acquired Darwin includes those related to use and disuse (probably under the influence of Lamarck's views); but the two things are not quite identical. Seidlitz and Nägeli seem to have been the first to note the difference.

Nägeli, in 1865, pointed out the lesson to be deduced from his experiments with Alpine plants. Transplanted to the lowlands, they lost in the first generation the properties acquired as the result of their Alpine habitat. Thus the acquired characters were not inherited. In the same year Seidlitz, a young follower of Darwin, in criticizing Haeckel suggested that it is doubtful whether acquired characters are inherited, and that to believe that they are is to revive Lamarckism.

Weismann's theoretical work owed much to Nägeli. Still under the influence of an earlier idealistic morphology, Nägeli believed internal organization to be the important factor in the life of the organism, while Darwin attached great importance to its history. Nägeli, who was a pure materialist, pictured inner organization as due to a definite arrangement of invisible particles in the protoplasm.

Weismann began by accepting this view, and combined with it the idea that acquired characters are not

[1] Y. Delage, *La structure du protoplasme*, &c., 2nd edition, 1903.

inherited. He wrote a series of articles in defence of this view, and met with very severe criticism. Herbert Spencer and Romanes strongly upheld the doctrine of the inheritance of acquired characters. Romanes did this as a true follower of Darwin, Herbert Spencer because his whole philosophical system depended on the truth of the doctrine. Human advance, according to him, depends on the inheritance of acquired moral and intellectual ideals. Wallace, starting from other premises, favoured Weismann's view. He believed that natural selection is practically the sole cause of evolution, and so could afford to neglect this very doubtful question of the inheritance of acquired characters.

Both parties quoted facts which seemed to confirm their views. Cases were cited of cats with short tails who had given birth to similarly deformed kittens. On the other hand, it was pointed out that, among the Jews, in spite of thousands of years of circumcision, this injury is not inherited by their descendants. The other side then pointed to Broca's measurements of the human skull. He had asserted that the average capacity of the human skull has increased, as the result of mental exercise, from 1,409 c.cm. in the twelfth century to 1,442 c.cm. to-day. So the controversy continued!

Brown-Sequard's experiments roused much excitement. He injured the brain of a guinea-pig, causing loss of sensation in the toes; by injury to another part of the brain he brought about a clouding of the transparent substance in a part of the eye. The animal bit off the injured toes, and Brown-Sequard asserted that both amputated toes and cloudiness of eye were transmitted to the offspring. The experiments were not confirmed, and the belief in the transmission of injuries is now universally abandoned.

The subject of the hereditary nature of certain diseases —e.g. tuberculosis, syphilis, &c., roused much interest. In some of these—e.g. mental diseases—the victims are born with a disposition to the disease. In other cases we must distinguish between an inherited disposition to disease and

the disease itself, which is not inherited but conveyed by a definite infective organism. What is inherited in tuberculosis is a certain bodily weakness, a predisposition; the disease itself is caused by infection from the environment. The disease bacteria might infect the egg cell or the spermatozoon; they might be transmitted *via* the uterus to the child. Such a process is not inheritance.

In more recent times, when the Darwinian theory had lost some of its original importance, the belief in the inheritance of acquired characters was revived. Upholders of this view asserted that they could now cite definite facts in its support—these facts, however, appear much less important than their upholders would have us believe.

Nägeli had said that structural modifications due to climatic changes are not inherited; the Norwegian botanist Schübeler now (1862) claimed to have proved that they are, but his observations were not confirmed by other workers. By exposing certain butterfly pupae (*Vanessa*) to an unaccustomed temperature, Standfusz (1905) succeeded in altering the markings of the butterflies into which the pupae developed. In one case this new marking was inherited, although both caterpillar and pupa developed at the normal temperature. Other writers, using similar methods, obtained even better results. C. Schröder (1903) found that changes in butterfly markings caused in this manner could be passed on through three generations. E. Fischer (1902) obtained similar results. A. Pictet (1902) succeeded in producing inheritable changes in the markings of caterpillar and butterfly by changing the food of the caterpillar.

Experiments on the immunity of animals to disease seem to point to the fact that this can be inherited in certain cases. Thus, Tizzoni and Cattaneo (1892) assert that mice immune against tetanus, and rabbits immune against rabies, pass on this immunity to their offspring. Behring makes similar assertions about diphtheria, Ehrlich (1891) in regard to the poisons abrin and ricin.

Among the Algae and Fungi many examples of the

inheritance of acquired characters are quoted. Goebel reports that *Micrococcus prodigiosus*, a bacterium which forms red patches when grown on an organic substration, loses this power if cultivated on an artificial medium; and this loss of the power to produce the normal red colour lasts for several generations, even when these are cultivated once more on potato. W. Jennings, a critical American observer, has written a very exhaustive account of the inheritance among the protozoa of artificially produced characters (1920).

Criticism has robbed many of these experiments of their importance. For one thing the newly acquired character is not fixed, but becomes weaker in the second and third generations, and is soon completely lost. Thus its inheritance suggests the continued effect of an artificial stimulation—not a change in the nature of the organism. No lasting change in constitution due to an acquired character has yet been proved. Mendel's work has given the problem of inheritance a different aspect, which is linked with pre-Darwinian idealism.

Recently the work of Kammerer has aroused much discussion. He had experimented for many years with the spotted salamander. Exposing these animals to special conditions of temperature, humidity, &c., on a background of a chosen colour, and also by performing on them definite operations, he claimed to have produced unmistakable alterations in the character of the organism. He asserted further that, by careful breeding, he had obtained conclusive proof that these acquired characters are inherited. Many scientists are sceptical about his results.

To Darwin the problems of heredity seemed clear and simple. With us the more they are analysed, the more complex they become. No observation, experiment, or intellectual speculation can alter the fact that each organism is an autonomous individual; it contains within itself the laws of its existence; and, in spite of the influence of its surroundings, it develops along its own lines. As to the nature of the directive force we know nothing.

XXIII

THE LATER HISTORY OF THE THEORY OF NATURAL SELECTION

§ 1. *Wagner.*

THE idea of Natural Selection and Darwin's theory of evolution are very closely connected. If natural selection does not occur, Darwinism must be abandoned. There was from the first one strong objection to the theory of natural selection. Suppose a new and advantageous variation to appear, the animal bearing it must mate with another which has not varied—hence the descendants would only inherit the advantage in a minor degree. Attempts were made to meet this difficulty. Could a factor be found that would separate the new variety from the non-varying form?

Wagner, the German traveller and ethnographist, suggested (1869) that, among the higher animals, the origin of new species is assisted by migration. If a new variety migrates into a neighbourhood where the type does not exist, it can develop there under new conditions, and it does not have to compete with the type for existence. So a local variety is formed, representing a first step in evolution, and the process is continued in the same manner. Wagner only applied his theory of migration to the higher animals. He thought that the lower forms of life are altered by the direct influence of the environment. Among those who favoured this theory were the American pastor, John Gulick (1905), A. E. Ortmann (1896), and P. Matschie (1895). In his later work Wagner himself considered evolution much more from the physiological point of view.

§ 2. *Roux.*

In 1881 a book was published dealing with the struggle for existence within the animal body. It attracted a good deal of attention, and Darwin called it the most important

book on evolution of its time. The young author's teachers, Haeckel and Weismann, gave it their approval. This writer, W. Roux, was already known by his work on the branching of the blood-vessels, which he had accounted for on purely mechanical principles based on the blood pressure on their walls.

Roux asserted that the struggle for existence between plants and animals may indeed account for the development of the coarser bodily features; for example, for the development of a definite type of foot, or the coarser features of the eye; but it can never account for the evolution of the finer details of structure—all those details so purposeful in every point. The thigh bone is constructed in correlation with the weight of the body and the way in which that weight is supported. But more than this; the finer systems out of which it is made are fitted together, much as a clever engineer might have fitted them, if he had set out to construct a column out of the least possible material, that should support a given weight. Similar fine details of structure, most admirably suited to their purpose, are to be found in every part of the body. The ordinary idea of the struggle for existence does not account for all this. One well placed Haversian system in its thigh-bone does not give any animal an advantage in the struggle; there are hundreds of thousands of them, and it is the right placing of this large number that gives to the bone its strength.

Roux suggested that such perfection is due to an inner struggle for existence between the various elements of the body. Imagine bone a homogeneous substance, and every part of it equally well nourished. If the weight rests on it, and muscles expand it in certain directions, some parts will be more used, and so more stimulated, than others. Those parts grow stronger, and rob neighbouring parts of both room and nourishment. They survive, the parts less favourably situated degenerate. Thus bone gradually evolves a structure, at once strong and well suited to its work. Other organs evolve in the same way. A mechanical

theory to account for the finer structure of each portion of the body may thus be formulated. To this process of strengthening and detailed differentiation Roux gave the name 'functional adaptation'.

The Darwinists accepted the new idea gladly. Roux himself admitted that his theory was to be regarded as an elaboration of the ideas of Haeckel and Preyer. Some critics asserted that the inner conflict between different components of the body is not analogous to the struggle for existence between individuals. Darwin himself, however, not to speak of his followers, had used the idea of a struggle for existence in many very different ways. There were others again who suggested that Roux's distinction[1] between external and internal 'purposiveness' is artificial. The talon of a bird of prey, for example, is eminently suited to its purpose of grasping the victim, and yet we cannot explain its structure as due to internal selection. These objections, however, were not raised until a time had come when doubt was being thrown on the whole idea of selection, and Roux himself was directing the attention of scientists to very different phenomena.

§ 3. *August Weismann.*

In his first book in support of the Darwinian theory (1868), Weismann expressed views akin to those of Nägeli and Wagner. They were not derived directly from Darwin. He attempted to reconcile Wagner's migration theory with Darwin's theory of natural selection. In 1876 he published another book, in which he said that both Nägeli's idea of a tendency towards perfection, and Haeckel's mechanistic explanations, contain some germs of the truth. Weismann now suggested that there are only two alternatives. Evolution is caused either 'by the action of a phyletic force, or by the reaction of the organism to external influences'. He favoured the latter view, which shows us that at this time his opinions were not far from Lamarckian. Further, he pointed out that the alternative

[1] G. Wolff, *Beiträge zur Kritik der Darwinschen Lehre*, Leipzig, 1898, p. 64.

view did not lead to any very satisfactory solution of the problem. Nägeli had also suggested that the organism reacts to external influences, but that, in addition, there exists a 'phyletic force', i.e. some inner organization, which determines the nature of that reaction.

Weismann did not absolutely reject such a fundamental controlling force, and this gave a certain lability to all his expressions of opinion. He feared, however, that this 'phyletic force' was a distant relative of the old 'Vital force', and this he was anxious to avoid at all costs.

Nägeli's belief in the dual nature of living substance was the impetus, the starting-point of all his philosophy, but Weismann's belief in a 'phyletic force' was sterile. What Nägeli regarded as a mere hypothesis, a deduction from his materialistic views, Weismann presented as a fact, an axiom, and all his further deductions depended upon it. He regarded protoplasm as the bearer of life. Life will continue, as long as that endures. If we examine the body of an amoeba, which consists of a single cell, and reproduces by fission, we see that it never dies a natural death. There is no corpse. The amoeba passes over into its two daughter cells. Hence the protozoa are immortal, apart from external accidents. Unfortunately this is not true of the multicellular animals, one of whom is Man. Here only the reproductive cells survive the death of the individual; their protoplasm passes directly (by continued division) into the protoplasm of the offspring, and so ever onward, to succeeding generations. Hence the protoplasm of the generative cells never dies. The body is a mortal shell clothing the immortal sex cells.

According to Weismann, then, death is not a necessary attribute of life. It is only an 'adaptation' which did not exist originally, but has been gradually evolved. The reason for this evolution is that, for the whole animal creation, eternal life is a 'purposeless luxury'! Other animals besides those actually in existence want to live. Hence, as a rule, the higher organisms only live long enough to ensure the lives of their offspring. Insects,

whose care for the young ends with the laying of the eggs, very often die as soon as the eggs are laid. Man, on the other hand, is granted a more extended life that he may bring up his children, who are for long incapable of an independent existence.

We listen with lively curiosity to Weismann's views. We almost agree with them. They sound unanswerable. We do not at first notice how much of its living content this theory of immortality has had to sacrifice. But on reflection do the facts fit the theory? During conjugation of infusoria, a portion of the body substance is eliminated. Does not this represent the missing corpse![1] In the hands of Darwin, his theory was a philosophy based on a very wide experience. In the hands of Haeckel, it became a medium for combating social reaction. In the hands of Weismann, with his theory of immortality, the evolutionary theory, unnoticed either by Darwinists or anti-Darwinists, put on a frock coat; it shook off everything elemental, everything passionate, everything human; and became merely a polite theory, interesting for discussion in the salon!

Weismann took Nägeli's theory that there is a difference between idio- and stereoplasm, and developed this idea. The body, according to him, is made up of different components—the red blood corpuscles are one component, eye colour another, a spot on the butterfly's wing, a birthmark in man, are examples of others. As the child's brick castle is built up of single bricks, so is the body built up of these components. If one stone of the set is lost, the castle cannot be built. If one component is missing, the building up of the living body is impossible. But the living body is vastly more complex than the box of bricks. First of all, the separate components are not dead stones by any means, for they are able to increase by division, so that each quality can be duplicated over and over again. Secondly, reserve components are tucked away in various

[1] R. Hertwig, 'Uber die Konjugation der Infusorien, *Abh. Akad. München*, 1889.

corners of the body—in the leg of the Triton the components of that leg are produced, for example; but there are also hidden away in other parts of the body various leg 'qualities' which only develop when the Triton loses his leg.

Thirdly, all the components of the future body lie hidden in the egg-cell. When this cell divides into two, four, and more segments, the components are separated to the right and to the left, above and below, to the front and to the back. Head components travel to the point where the head will develop, foot qualities to that spot where feet shall develop, and so the mature body gradually arises. These qualities, however, possess an inherited power of division, and hence innumerable groups of qualities arise. These are not all used up during development; many groups wander into the newly formed reproductive cells, or to places where a new body may arise by budding.

We must picture these components as real, extremely small granules of matter, which are aggregates of even smaller granules; they are all present in the egg nucleus.

It is almost impossible to give any short description of this extremely complicated network of components, each component represented by a granule of living substance. No army is so numerous, nor led in so orderly a manner, as Weismann's hypothetical granules. Millions of them lie dormant within the egg, arranged according to definite laws, in companies, battalions, and groups of higher and higher order. When development begins, they separate just at the right moment, until in the cells of the mature tissue only a few are present, and these live, struggle, and die there. Millions of reserve granules are waiting to replace those that die, while new armies of them arise in the reproductive organs. These leave the body with the egg to form a new body essentially similar in constitution.

Thus Weismann came to the conclusion that all the components of the adult body lie hidden in the egg and sperm nuclei. He called the nuclear protoplasm which

contained these components, the *germ-plasm*. During segmentation it divides to form new nuclei, and it is always present in any part of the body which can produce a new organism—in the reproductive cells, in the cambium of plants, and in all those parts which may undergo regeneration. In other parts of the body the nuclear protoplasm only contains a few of these qualities—such protoplasm Weismann called *somatoplasm*.

Weismann wrote many books in which he developed this theory of the germ-plasm. In 1892 he rounded off and completed his theory in a large work dealing with heredity, which fascinated contemporary biologists. It was, of course, obvious that his pre-supposed granules—*biophors*, *determinants*, *ids*, *idants*, as he called them—were mental concepts, but they were accepted almost as objective realities by a large part of the scientific world, who passed them on to the lay public.

Is the whole organism already present in the egg, or is it only formed during development? This problem had already occupied the early Christian fathers, and attempts to elucidate it had exercised the embryologists of the early part of the century. Here, in this theory of Weismann's, the question is answered in conformity with the views of the preformationists. If all the qualities of the mature organism are already present in the egg, in the form of minute granules, what is this but a revival of the doctrine which still makes us smile when we study the *Naturphilosophen* of the eighteenth century? Weismann and his contemporaries were hardly conscious that he was going back to their conceptions. He imagined himself far superior to Bonnet, because he did not think that the egg contains a man in miniature. Had he not advanced to the idea of granules? What progress! As if Bonnet had ever taught anything different! He too had only asserted that all the qualities of the adult must be already present in the egg, he too had the modern 'granules' in mind, and by them he explained regeneration, even as Weismann did.

When Weismann produced his theory of an immortal germ-plasm, round which the rest of the body forms a shell which is only in mechanical continuity with the reproductive cells, he inferred that characters acquired during the life time of the individual must die with that individual, since they merely represent a change in the body, in the somatoplasm. The germ-plasm, shut up in the reproductive cells, cannot be influenced by bodily changes (due to injury, to exercise, to habitat and the like). Only those changes which arise in the germ-plasm itself can affect the heredity of the organisms. He was able to prove that injuries (mutilations) are not inherited; nor did he believe that changes due to use and disuse (the so-called functional changes) are inherited.

In the discussions which followed the publication of his views, Weismann admitted that the effect of the action of the environment on the body might be inherited, if the germ-plasm were influenced too. Such changes, though directly due to the action of the environment, would in that case be inherited. The whole discussion, however, was fantastic. Weismann's denial of the inheritance of acquired characters was not due to any new insight into natural processes. He deduced it from a theory which was, in its turn, only a deduction from the unproven hypothesis that there is a difference between the germ-plasm and the somatoplasm.

In this matter of the inheritance of acquired characters biologists were separated into two camps. Those who believed in such inheritance were called Neo-Lamarckians, while Weismann's followers were called Neo-Darwinians.

Natural selection, according to Weismann, is the only factor which can produce new species. That part of Darwin's theory which rests upon the assumption of the inheritance of acquired characters must be rejected. We must explain the origin of new species with the help of inborn variations only. Those which are useful will be retained by natural selection, the others will disappear. Hence the qualities of any organism are merely those

qualities which have been found useful to it—they have no other meaning:

'The eye of the frog is a very imperfect instrument when compared with the eye of an eagle or of a man; but it is good enough for seeing the crawling fly or the wriggling worm—good enough, that is, to ensure the nourishment of the species. Even the eye of the eagle is not an absolutely perfect optical instrument, but it enables the bird to discover its prey with certainty while hovering high up in the air, and this is enough to ensure the existence of the species; hence any further improvement as the result of natural selection is excluded' (A. Weismann, *Aufsätze über Vererbung und verwandte biologische Fragen*, 1892).

Arguing thus, Weismann selected the one 'almighty' principle of evolution; by doing so he made it unreal. Darwin the observer, believed that he had actually seen natural selection in operation, and pictured its influence as controlled by other factors. In this belief he was mistaken; his 'utilitarianism', and his theory of natural selection, were really nothing but logical principles, by means of which he was endeavouring to interpret nature. Weismann seized on these principles, and set them up as axiomatic truths. He abandoned natural selection as a fact of experience and made it a logical principle by means of which all the qualities of the organism can be and must be explained.

The doctrine of chance could be taken no further; all that now remained was to look for some compromise with reality.

Inspired by Roux's ideas, to which we have already referred, Weismann published a new hypothesis in 1895. He developed the idea further, and a year later suggested that there is a struggle for existence within the germ—a process which he called 'germinal selection'. He now endowed his hypothetical granules with new capacities. He supposed that their size and vigour were proportional to the size of the component they produced, and dependent upon the amount of food they received. Those granules which are by nature more robust will attract to themselves more nutriment, and will grow strong at the expense of

their weaker neighbours—hence the growth and development of the one results in the weakening and decay of the other. Let us assume, for example, that an animal becomes accustomed to life in darkness. Its eyes become useless, even harmful, since they can be so easily injured. Among its descendants some will by nature have weaker sight. These are as well equipped for the struggle for existence as are the sharp-sighted, since sight is now useless. There will be indiscriminate breeding between the weak and the strong of sight, and this will lead in time to degeneration of the organ of vision. Weismann called this indiscriminate breeding *panmixia*, and endeavoured to explain the origin of rudimentary organs as due to this cessation of selection.

Some of Weismann's critics doubted how much *panmixia* would explain, and particularly whether a struggle between individuals could ever cause an organ to disappear entirely. Weismann admitted the validity of this objection, but thought that his theory of germinal selection would solve the difficulty. In the case referred to, for example, the granules determining weak sight are less potent than granules determining the other qualities of the animal; in the struggle for nourishment which takes place during development, the 'sight' granules are consequently defeated; this continues until, ultimately, they are totally destroyed. The result is that the eye completely disappears in animals who continue to live for generations in total darkness.

It was also suggested that this struggle for existence within the germ would assist in the production of favourable variations, and in the accentuation of such variations; in the origin of whole groups of organs, of monstrosities, mutations, specific talents, &c.

Thus in the end Weismann admits that external conditions (temperature and the amount of food, for example), *can* produce modifications, not only of the body itself, but also of the germ-plasm, and that some of these may be hereditary.

For the influence of the environment extends to the granules in the germ-plasm, strengthening some and weakening others. It can happen, for example, that, for some reason or other, the strength of one granule will increase. It begins to oppress its neighbours; this causes an increased development of the organ which those granules represent. This increased development enables the animal to be more successful in the struggle for existence; this leads to a still greater nourishment of the granules which represent the organ in question, and hence to an even greater development of that organ in the succeeding generation, and so the process continues. In this way, according to Weismann, we can explain why variations do not sway about blindly, now here, now there, but follow a definite course, which is advantageous to the animal.

Weismann's theory rapidly gained and almost as rapidly lost favour among men of science. There are to-day very few who believe in his distinction between the germ-plasm and somatoplasm, or in the immortality of the protozoa; in the omnipotence of natural selection, or in *determinants*, *ids*, and *idants*—although this dead material is still dragged into text-books.

Nevertheless Weismann's influence was great, and its effect was felt beyond the world of biology. It led to a fuller investigation of the problems of heredity, and, further, to the application of the Darwinian theory to the study of the cell-nucleus. He impressed upon investigators the idea that the organism must be resolved into its component parts; by denying the omnipotence of natural selection, he paved the way for Neo-Lamarckianism; finally, those who in the end became sceptical about the Darwinian theory began by being sceptical about Weismann's ideas. It was his influence, too, which made biological thought become so much more superficial, as it became fashionable to refer every problem to the phenomena within the cell. Haeckel and Weismann were very strongly contrasted characters. Both were the apostles of

Darwin. One became the leading figure in anatomy and embryology, the other the guiding force in histology. Haeckel silenced von Baer, the embryologist, and returned to the ideas of Meckel. Weismann ignored Baer, the epigeneticist, and went back to the ideas of the tedious and insipid Bonnet.

XXIV

PSYCHOLOGY

§ 1. *The Darwinian School.*

DESCARTES held that only human beings possess souls. He compared animals with the automata which were so popular in his time. In the eighteenth century this theory was challenged, and many thinkers claimed that animals have souls. A hundred years before Darwin, Condillac (1755) propounded a theory of the origin of the animal soul. He believed that every animal has at the beginning as much intelligence as has a human being, but that its development is retarded by want of experience.

'Objects produce impressions upon the animal, he has sensations of pain and pleasure. These cause the first movements of the animal. To begin with these are very uncertain, and are not under his control, for he does not know how to control them. The same desires, the same necessities, return again and again; the movements are repeated so often that there is no more trial, no more uncertainty. The animal has become accustomed to act and to judge. In this manner desires produce impressions on the one hand, the corresponding actions on the other.'

Condillac asserted further that animals only remain less developed than man because, their bodies being less perfect and their sense-organs less highly developed, their experience is necessarily less extensive. His ideas really represent a development of Locke's philosophy.

Darwin was not acquainted with the work of Condillac, but he held the same popular ideas about the nature of the animal soul. When we read what he says about insect psychology we are reminded of the words of those collectors of insects who do not hesitate to kill the souls of their victims by using a bottle of alcohol, while all the time they talk in a somewhat affected manner about the wisdom of insects!

Darwin believed that all animals possess souls, something resembling the human soul; he based his whole theory of sexual selection on this view, endowing animals with tastes similar to human tastes. He thinks that the lower animals have no such taste, for

'their sense organs are not sufficiently developed, nor is their mentality high enough, for them to be able to appreciate beauty, or any other kind of attractive mechanism, or to be capable of jealousy. Among the higher animals, however, sexual selection depends upon the will, the desire, and the choice of the opposite sex.'

These words show us that Darwin pictured animals as thinking, feeling, and acting as human beings do. He taught that instinct is an acquired character, and he dealt with it just as he would deal with any physical character whatsoever. Here he writes that he will not attempt to explain the origin of life, only to show how the differences between animals have arisen, as the result of natural selection. There he says that he is not attempting to explain the origin of the mental powers, only the diversities of instinct; he is convinced that these differences have arisen as the result of natural selection. Animals differ both in body and in mind. Both sets of qualities are inherited. If a mental quality proves of value in the struggle for existence, it will be retained, passed on to posterity, and increased. Thus new abilities arise in a quite mechanical manner. Only a few such mechanical factors are of influence. Animals with their lower intelligence have some degree of understanding; realizing the advantage of some new habit they adopt it; a habit is formed which can be inherited—it becomes an instinct.

Animal instinct was explained by Darwin in this fashion. These instincts, in spite of all their diversity—as seen in domestic animals, in the cuckoo, among bees, in the ant-heap—do not seem to have been regarded as very remarkable, either by Darwin or by his opponents.

Darwin's method was used by other investigators. Among them Forel, the Swiss specialist on ants; Buttel-

Reepen (1900), who studied the life of the bee and the wasp; Wundt (1897), who, in his writings on the animal soul, paid particular attention to the pigeon's sense of hearing; Romanes (1883), in his book on the Intelligence of Animals; Lubbock (1899), in his work on Instinct; W. A. Nägeli (1896), the physiologist; Wallace (1889), who looked upon all animals as very like human beings—only less clever and less experienced. Brehm's popular work on animals furnishes the best example of the application of this philosophy. Anecdotes and travellers' tales, truth and falsehood, the most intellectual and the most trivial—all confused together.

§ 2. *Wasmann.*

One man of science was strongly opposed to this anthropomorphic psychology—the entomologist Wasmann. Schooled in dogmatic theology and in scholastic philosophy, he sought, and not without some success, to apply the doctrines of St. Thomas Aquinas to the problems of comparative psychology. Wasmann held that animal instinct is quite distinct from intelligence, nor is it to be regarded merely as a lower grade thereof fixed by inheritance (which was the view of the evolutionists).

In the various activities of the organism he distinguished between:

(*a*) Purposeful reflex actions, which depend solely on the nervous mechanism, and not on sensation, e.g. the action of the heart muscles, the peristaltic movements of the intestine during digestion, sneezing, &c.

(*b*) Instinctive processes—where sensations play their part, and bring about purposeful activity. Instinctive actions are 'Deeds which are the result of some sensuous desire. Their carrying out is controlled by the *senses and organs of sense-perception.* These two qualities distinguish them from mere reflex actions.'

(*c*) Intelligent Actions. Here there is consciousness of the end to be attained. By this criterion we can distinguish between intelligent actions and merely instinctive ones.

He further holds that intelligence consists merely of the power to relate ideas to one another, and to draw conclusions therefrom. To make his views clear Wasmann gives a detailed analysis of modern theories about the souls of animals. For him only man is 'intelligent'. Animals, even the highest, are dominated by instinct. They have no power of abstract thought, no capacity to formulate general ideas, no vision of the purpose of their actions. He also shows that the views of the schoolmen may still be regarded as living ideas. Though they may have been hidden beneath a mass of new theories they have survived till the present day.

Wasmann's work did not attract any attention from the scientific world. This was partly due to the conviction that scholasticism cannot possibly be reconciled with modern science, and partly to the fact that animal psychologists receive little training in philosophy; but the chief cause was the realization that Wasmann had not arrived at his philosophical views by studying the facts of animal life. They did not represent his own individual expression of the results of his personal observation. It was felt that he had accepted scholasticism 'ready-made', and now was searching for facts to support his views.

When we note how uncertain Wasmann becomes when he leaves the well-beaten path of scholasticism we cannot help coming to the same conclusion. Wasmann agreed quite uncritically with modern scientists in believing that we can only understand the psyche of animals (and consequently of men too) by indirect means, by analogy with our own subjective life. Such an assumption is foreign to Aristotelian philosophy, and is the fruit of modern subjectivism. Aristotle and the scholastics believed as firmly in the psychical life of other men as they did in their own individual existence.

Wasmann's distinction between reflex actions and sensations, according to the presence or absence of sensation, is not valid, as his opponents have shown. We have no scientific criterion of the subjective, so that we cannot

use it as a basis of scientific classification. Further, since it would seem that intelligence develops out of instinct, and is not added to it as something different in essence, the gulf that Wasmann sets between the two cannot express the truth.

The Darwinian idea that animals possess a rudimentary intelligence probably contains a nucleus of truth. This truth, however, cannot be revealed by the primitive methods which were formerly adopted by the evolutionists.

Wasmann's investigation of the different methods of obtaining knowledge seems to be based on actual observation, and here again he concludes that there is a difference between animals and Man. He distinguishes between:

(*a*) Individual learning: (i) by the instinctive exercise of inborn reflex mechanisms; (ii) through the senses; (iii) through sensual experience and the intelligent application of experience gained under familiar circumstances to new and unknown conditions.

(*b*) Learning by the aid of some external influence: (i) by stimulation of the imitative faculties; (ii) by training; (iii) by intelligent teaching.

Only human beings are capable of learning in all the six ways. Animals may learn in the first way only, or in the first and fourth, or in the first, second, fourth, and fifth, depending on the degree of the animal's intelligence.

§ 3. *Scientific Psychology.*

Fechner's suggestion that there is a parallelism between the psychical and the physical lies at the root of modern 'scientific' psychology. This psychology pictures the world as consisting of two kinds of realities—the subjective, known only by the ego; and the world of objective realities, open to all.

If we are to speak of the soul at all it is identical with the former—with subjective reality, while everything else is a part of the not-soul, of objective reality. These ideas bear a close relationship to those of Fechner; they are

also akin to those of Helmholtz, and hence can even be connected with the earlier views held by Müller.

This modern psychology was really a development of the psychology of Descartes, but it also contained much that was pure anatomy—facts relating to the structure of nerves, ganglia, cerebral centres, and the like. Much attention was also given to the construction of delicate apparatus. The soul was declared to be one attribute —when not the sole one—of living material, and to be the result of a definite nervous organization.

It was believed that, by skilful use of the scalpel, the microscope, and well-stained sections of the brain, all the problems of the soul could be solved. A curious version of this materialistic psychology was given by Gustav Jäger (1880), an evolutionist of the old school. He studied the odours of various animals, and concluded that each individual emits a characteristic odour; that, further, each family, each race, each order, each species, emits certain definite odoriferous substances. He suggested that these odours determine the relations of animals to one another. Predatory animals only follow prey who emit a smell which they like; the victims flee because they find the odour of their enemy unpleasant. He believed that sexual love, feelings of family or of racial unity, were founded on the diffusion and the detection of definite odoriferous substances. Fertilization is brought about first of all by odours emitted by egg and sperm respectively, an *aura ovularis* and *seminalis*.

Darwinists gave their approval to the theory. Jäger, however, expressed his ideas in so paradoxical a fashion that they did not gain a very wide acceptance. He was often ridiculed. Nevertheless his ideas come into prominence every now and again—although they did not exert any influence upon the scientific world. Mantegazza, the Italian writer, made use of them in his notorious book *The Physiology of Love*; Bethe, the psychologist, returned to them in his endeavour to explain the machine-like precision exhibited by the lives of the bee and the ant; he

was attempting to refute the prevailing views about the mentality of the lower animals—views which he considered to be quite unscientific. Loeb used the same ideas more successfully in his endeavour to build up a 'comparative physiology' on a chemical basis.

The work on 'tropisms' which was begun by Loeb and Sachs represents an important branch of comparative physiology, and forms an experimental introduction to comparative psychology.

Jenning's 'Trial and Error Theory' occupies a position of some importance. He believes that many of those directed reactions to stimuli which are seen in both the plant and the animal kingdom, begin as blind gropings in any direction; and that only when the external stimulus reaches a certain intensity do these movements become directed.

The science of comparative psychology has undergone considerable development in recent years. Many observers have gone back to the view that the animal is a kind of primitive man, and they have greatly added to our knowledge of the animal soul by observation of the habits, instincts, even the 'sensible acts' of animals. To this type of work belongs Forel's work on Ants, Buttel-Reepen's on Bees, and Fabre's on insects. Much recent investigation is directly related to the work of Loeb, and is physiological rather than psychological. This is particularly the case with the work of Bethe, Bohn, Uexküll, and a whole series of workers on the so-called 'tropisms'. Modern experimental psychology of the American school has also derived its inspiration from Loeb, e.g. Jenning's very original studies, and the experiments of Yerkes, and others. Jenning's work led on to modern psychology of the *behaviourist* school. In this work, as developed, for example, by H. Watson and E. L. Thorndike, the introspective study of consciousness is rejected. They examine objective reactions only, both of men and of animals.

XXV

THE LAMARCKIANS

§ 1. *The Influence of Lamarck.*

LAMARCK'S work cannot really compare in importance with that of Darwin, although a vote taken at the present moment might be in favour of the opposite view.

Look at the great historic movement caused by Darwin's work, see how noteworthy were both his supporters and his opponents, a Nägeli, a Haeckel, or a Huxley; and compare this with that short-lived movement called Neo-Lamarckianism. Remember that this new movement would never have occurred without Darwin; that it was not possible until Darwinism had lived out its time. Then we shall be able to judge rightly of the respective importance of Darwin and Lamarck. Darwin's book is so important in the history of science, because the author gives us there of his best. Every word of it breathes earnestness. His ideas have formed a part of the great stream of human thought. Full of doubts he gropes blindly for the truth, and when he believes, he believes with all the strength of conviction. Against this all that Lamarck has to give are a few suggestions. Nevertheless Lamarck's ideas have left their mark.

Darwin himself only saw in Lamarck's teaching vitalism under a somewhat thin disguise. He believed that his own point of view was quite different from that of his predecessor, and, as early as 1844, he pointed this out.[1] Nevertheless, he believed that the Lamarckian factor—namely, the inheritance of acquired characters—was of some importance. There were some workers who could not see any very great difference between the views of

[1] His actual words were: 'Heaven forfend me from Lamarck's nonsense of "a tendency to progression", adaptations from the slow willing of animals, &c. But the conclusions I am led to are not widely different from his, tho' the means of change are wholly so.' Darwin's *Life and Letters*, vol. ii, p. 23.

Lamarck and of Darwin. Darwin was often obliged to discuss this subject with Lyell and Huxley, and to assure them that the two views were far removed from each other.

Many investigators were led back to Lamarck by a desire for historical accuracy, by an endeavour to see what connexion there was between Darwinism and older views; among these were Haeckel and Huxley. Lamarck had always received much support in France; so that it is not surprising that the French began to emphasize the importance of their fellow-countryman's work.

Since 1880 Lamarck's name has been referred to more and more. Roux's theory of functional adaptation, Weismann's denial of the inheritance of acquired characters, the gradual falling-off in the enthusiasm for Darwinism, all these factors helped to bring this about.

In all this whirl of conflicting opinions it is noteworthy that no one seems to have turned back to the work of Erasmus Darwin, the grandfather of Darwin. He was writing before Lamarck, and in a much more original way, giving expression to very similar views about the origin of the organic world; his influence on Darwin was also a more direct one. How, then, are we to explain that to-day Lamarck is famous, but Erasmus Darwin is not? Is it that we do not meet, in his work, those phrases so often cited in modern controversy?

Lamarck did not state his theory at all clearly. His words suggest that there are blind mechanistic forces at work in nature, but his ideas are purely vitalistic. His followers continued the discussion, and there was the same lack of clear thinking among them. Even to-day, among those who discuss Lamarck's work, some consider that his philosophy is mechanistic, others hold it to be vitalistic.

C. Detto (1904) holds that Lamarck is a vitalist, and rejects his views on that account. M. Kassowitz (1905), on the other hand, holds that his ideas are mechanistic, and cites them to controvert Neovitalism. A. Pauly (1905), again, declares that Lamarck, because of his vitalistic ideas, is a genius, and he dismisses his mechanistic theories,

declaring them to be illogical. J. P. Lotsy (1906), on the other hand, says that Lamarck was a mechanist, and a very able mechanist; his excursions into vitalism represent mere misapprehensions on his part, for which he must be forgiven! Pauly, following Lamarck, believes that it is the *activity* of the living organism which is all important; Lotsy also following, as he believes, in his footsteps, emphasizes its *passivity*! T. H. Morgan (1903) has deduced something quite new from Lamarck. He says that Lamarck's assertion was not that

'the desire of the animal for a particular part has led to the development of that part; . . . in reality he only maintained that the desire to use a particular organ to fulfill some want, led to its better development through exercise, and the result was inherited' (T. H. Morgan, *Evolution and Adaptation*, 1903).

K. Goebel (1904) holds that Lamarck assumed the existence of certain evolutionary factors which are purely mental, and that in this he was mistaken.

G. Steinmann (1905) wants to introduce Lamarck's ideas into palaeontology. He discovers, in Lamarck

'an eye for history, an historical method, which placed him quite a hundred years in advance of his times, and enabled him to recognize laws which can, even now, only be properly understood when we have a background of history, and when they are considered in relation to this historical background' (*Die geologischen Grundlagen der Abstammungslehre*, 1908).

Steinmann, however, does not accept the vitalistic theory, and in his eyes Lamarck is a mechanist (although Steinmann never actually says this!).

All that Weismann said about Lamarck was that he held the erroneous view that acquired characters can be inherited.

We will cite Schopenhauer's view (*Über den Willen in der Natur*, 1854) to crown this list of 'explanations' of Lamarck. All the workers we have named, however diverse their opinions about Lamarck, yet agreed that his importance lay in his assertion that organisms are all linked

up by their history. Schopenhauer, however, after saying that Lamarck was 'a first class zoologist', pointed out the correctness of his assumption that the structure of the animal is the result of its own endeavours. On the other hand (according to the same authority), he made a great mistake in assuming that there is any historical connexion between organisms! Kant, continued Schopenhauer, has banished such mistakes from Germany once and for all, together with the absurd and coarse French atomistics and the popular English physico-theological ideas.

To-day, many call themselves followers of Lamarck. Most of modern Neo-Lamarckism [1] arises, not from a conviction that Lamarck was right, but from the feeling that Darwin was, in part at least, wrong. Many of this school simply oppose the idea of the will to the Darwinian idea of chance, soul to matter, understanding to mechanism, and function to structure.

§ 2. *Cope.*

E. D. Cope (1840–97) an American palaeontologist who made a special study of vertebrates, held views about evolution similar to Lamarck's. These first appeared in scattered papers, and were only later collected and published in book form (1887). His writings were hardly noticed in Europe. In developing his theme he paid little attention to the views of other modern workers, nor did he seek any opportunity of explaining his ideas to other investigators. Hence his work was somewhat neglected.

Cope was a strict Lamarckian; he thought evolution in the plant kingdom to be the result of the action of mecha-

[1] The name Neo-Lamarckism was introduced by Packard. See his work *Lamarck the Founder of Evolution*, p. 396.

G. Wolff, in his book *Die Begründung der Abstammungslehre* (Munich, 1907), recognizes that Neo-Lamarckism represents the death-knell of the whole idea of evolution. It is, however, very difficult to understand how this able critic, having rejected the anatomical and embryological facts as insufficient to support the ideas of phylogeny, then suddenly finds a proof of the same in the so-called rudimentary organs (ibid., p. 24).

nical forces, and that the lower animals, together with certain very sensitive plants (e. g. Mimosa), are altered by continually recurring stimulation. It was his view that in higher forms of life an unconscious endeavour brings about evolution, while in the highest forms conscious striving stimulates to new kinds of activity. Natural selection plays its part in evolution. It is, however, not the only factor; it only serves to the retention of useful elements and does not determine their origination.

Cope rejects Lamarck's view that the soul is derived from non-living forces, and that it only becomes a factor in evolution in the higher forms of life. A vital force, he asserts, is the cause of all evolution. It determines why physical and mental forces act, now on this part of the body, and then on the other:

> 'If then, we grant the propositions, first, that effort and use modify structure; and, second, that effort and use are determined by mind in direct ratio to its development, we are led to the conclusion that evolution is an outgrowth of mind, and that mind is the parent of the forms of living nature.
>
> 'If structure is the effect of the control over matter exercised by mind, it is evident that evolution of mind must be directly followed by the corresponding development of organs. . . . But the animal mind being generally occupied with simple functions, its expressions in structure are usually nothing more than the progressive creation of improved instruments for obtaining food, resisting climate, escaping enemies, and reproducing their kind' (E. D. Cope, *The Origin of the Fittest*, 1887).

Cope calls this force the 'growth force', and considers its laws of action. It reminds us of Nägeli's 'principle of perfection'. This growth force does not influence all parts of the body simultaneously; in some parts evolution goes on quickly, in others slowly. In man, the development of the head was rapid, while that of the arms and the hips was retarded. Compared with his other teeth, the canines of man show retarded evolution.

Cope held peculiar views about the evolution of species. Darwin believed the difference between genera and species

to be merely quantitative, individuals of the same species having more characteristics in common than have the different species which form the genus. Cope's views were similar to those of Agassiz. He taught that each organism possesses some characters which denote its species, others denoting the genus, still others marking the order. Hence the same species can be repeated in different genera; evolution may bring about a change in the characteristics of the species, the characters of the genus remaining constant; or, conversely, the genus characters may change, while those denoting the species remain unaltered. Consequently it is very probable that 'the same specific form has existed through a succession of genera and perhaps in different epochs of geologic time'.

Birds that screech and birds that sing, Diptera and Hymenoptera, furnish us with examples. Many species of screeching birds he supposed to have changed the character of their call and to have become singing birds, while retaining all the other characteristics of their original species. He believed that Diptera gave rise to Hymenoptera in a similar manner. Cope calls such series of organisms as the screeching and singing birds, Diptera and Hymenoptera, placental and non-placental mammals, homologous series, and corresponding species in the two series heterologous species.

One objection brought against Cope's views on classification is that no transitional forms between separate groups are known to palaeontology. His theories have, however, never been subjected to any very critical examination by zoologists. Influenced by the theories of de Vries, many recent investigators have come to agree with his ideas. Osborn, Hyatt, Scott, Waagen, Neumayer, and Steinmann, among palaeontologists, Packard the zoologist, and Geddes the botanist, have expressed views similar to those of Cope.

Rather less closely related to the views of Cope are those of Ettingshausen and Krasan, the Austrian palaeontologists (1888 onwards). Studying extinct oaks and beeches,

they came to the conclusion that all the specific characters of modern oaks or beeches were to be found in the ancestral forms, but that these were originally undifferentiated and combined in every possible way. The ancestral form, for example, bore many types of leaf, each such type now characterizing a definite species. 'Each tree seems at that time to have possessed an unlimited capacity for producing new kinds of leaf. Heredity hardly existed; the same type of tree might produce the same form of leaf in very different parts of the world, but this would not necessarily be the result of any very close phylogenetic relationship' (C. von Ettingshausen, *Untersuchungen über Ontogenese*, 1890). 'The story of the evolution of the various kinds of oak is not a story of the production of new forms which did not exist previously; it is rather that all the various possibilities which originally existed have been realized in the course of time. Thus from one very varying species, a whole series of varieties has been evolved. These lack the freshness and power of adaptation of the original ancestral form.'

These authors consider that the unit elements of structure, i.e. the morphological characteristics of species, are immutable; the infinite variety of species is due to varying combinations of these elements. They agree with Cope in believing that these elements represent something unchanging and having an independent existence. They also agree with him in the view that morphological similarities do not necessarily represent relation by descent. They believe, as he did, that some characteristics of a plant evolve, while others remain constant; that the transition from Cryptogam to Phanerogam, for example (e.g. from *Lepidodendron* to *Araucaria*), occurred in this manner. The plant retained the vegetative habit of its ancestor, but completely altered its method of reproduction.

C. Brunner von Wattenswyl, an Austrian entomologist (1873), believed that evolution results from the action of mind. In man there is a desire for perfection which enables him to rise above the utilitarianism of everyday

life. So, in nature, the leading principle is an urge towards an ever higher goal; this may be at one time the structural perfecting, at another the beautifying of the body. Like Cope, he taught that one genus of animals may be transformed into another suddenly by saltation, while the specific characters remain unaltered. Brunner believed that the species is merely the genus 'raised to a higher power', as he calls it.

§ 3. *Eimer.*

Eimer, the zoologist, first became known by his criticism of Weismann. He had been publishing work on development since 1874. He began with a study of the wall lizard (*Lacerta muralis*) which is very variable both in colouration and in marking. This work received little attention. At that time research was chiefly of the genealogical tree type inspired by Haeckel. Microscopic work was emphasized and observations on colouration were dismissed as 'very inexact'.

In 1888 Eimer published a treatise on the origin of species, constituting the second part of a work on the colours of butterflies. Later he applied his theory to other animals. In his work on lizards he suggested that all lizards tend to pass through the same series of phylogenetic stages in regard to marking and colouration, but that the development of each individual is arrested at a different point in the series. The wall lizards, for example, were originally black with longitudinal stripes. More recent lizards became spotted and lighter in colour. These changes were due, he thought, to the action of some internal cause. The most highly developed animals are very brightly coloured and transversely striped. We can still find examples of each of these stages in evolution. Black lizards have survived on bare rocks, where, looking like shadows, they have escaped the eyes of their enemies. In undergrowth brighter colours are developed, for here only those survive who have reached this stage in development. Hence natural selection is purely negative in its effect,

getting rid of inappropriate forms, but not producing new ones. According to Eimer, these changes of colour first make their appearance on the hinder parts of the body, and they spread from thence forwards. He asserts, further, that they first appear in the male, later in the female.

Eimer found similar phenomena in butterflies. The original colouration of the butterfly consisted, according to him, of eleven longitudinal stripes on a light-coloured wing. (Our modern butterfly, *Papilio podalirius*, which has a yellow wing with ten longitudinal striations, is assumed to be very near to the ancestral form.) From this form later types developed. The more recent they are the shorter their stripes, until these become merely spots such as occur in the swallow-tail butterfly, *Papilio machaon*. These spots then spread transversely, giving rise to forms like *Papilio xuthus*. Finally, they spread over the whole wing, producing a uniform black colouration.

Eimer, like Nägeli, thought that natural selection was of secondary importance. The principal cause of evolution is that the organism outgrows the limits of individuality. This phyletic growth would be favoured by climate, nutriment, and so on, but it is the result of something in the original constitution, and it tends to the production of new forms; hence it is the immediate cause of variation. Eimer therefore concluded that variation can only proceed in one direction—not in many, as Darwin had suggested; for this reason he called his theory *Orthogenesis*.

Eimer undoubtedly arrived independently at his theory of orthogenesis. It is extraordinary that, although Eimer constantly refers to Lamarck and Cope and applauds their theories, nevertheless he does not realize that their views include his idea of orthogenesis. It was foolish of him to contrast his views with those of Nägeli; he had no grounds for doing this, for the two views are very closely related. He also strongly emphasized the differences between his ideas and the theories of Weismann; he objected in particular to Weismann's denial of the inheritance of acquired characters. He had no reason to do this, for the

matter was not only not vital for his theory, but it was actually in agreement with it.

Before the time of Eimer, Taylor had pointed out that the markings in plants and animals are due to lines determined by the internal structure of the body.

§ 4. *Samuel Butler.*

We do not find that Butler's name is often mentioned in the literature of Darwinism. He was eccentric and was guilty of a personal attack on Darwin. His name was never mentioned by the Darwinists in their discussions. They seem to have banned it in honour of their master.

In his book *Life and Habit* (1878), which is full of original psychological observations, Butler points out that we may look upon phylogenetic development as a continual process of becoming accustomed to new activities. He gives many examples of actions which, having been constantly repeated, become automatic. The more we are practiced in any art, the less conscious are we of the manner of its performance, and, indeed, consciousness disturbs that performance. A pianist, playing some well-known piece from memory, will suddenly stop if he attempts consciously to control his fingering.

Butler says that this is what happens in life. We are so accustomed to existence that it does not occur to us to think about it. When we do begin to think, we begin at once to doubt; and we formulate the phrase *cogito, ergo sum* to reassure ourselves of that existence. We may assume that many actions now performed quite automatically were once performed deliberately and for a conscious purpose. We have, for example, trained ourselves most marvellously to breathe. A newly born child makes a few attempts at breathing, like a man trying to remember some procedure that he has formerly practised; these attempts only last a few minutes. Swallowing, digesting, seeing, hearing—we are able to do all these things unerringly and unconsciously because they have been done by thousands of generations before us.

It is the specifically human activities—speech, the maintenance of the upright position, art, science, which require conscious performance, and are most under our conscious control. Man has only recently raised himself to the level of these attainments, and each man has to practise them anew. Eating, drinking, sobbing, breathing, seeing, hearing, are functions which our pre-human ancestors had already acquired, and these are now more subconscious. Least controllable of all are the activities which were already practised by pre-vertebrate ancestors, e.g. the circulation of the blood.

We may regard the development of the embryo as the repetition of well-practised and at first conscious attempts to form flesh, bones, beak, and so on. Even the protozoa, when they form shells or stretch out pseudopodia just where these will help them to obtain food, are performing actions at once conscious and purposeful. They pass on their experience to their descendants; we may imagine, then, that the personality of the ancestral protozoon continues to exist in these descendants and is constantly being enriched by new experiences.

Since the whole of the present organic world has been derived, by an unbroken series, from some original protozoon, we may assume that the personality of the ancestral protozoon continues to live in all existing organisms. And not it only, but the personalities of all those later direct forefathers, who lived, amassed experiences, and so brought about the progress of the organic world.

All organisms then, from the single cell to Man, had originally a common personality. Later these were separated into various centres of memory, hence into separate personalities; and these lost all sense of their near relationship.

The life of an individual then, is a repetition of all those things which this individual has done a billion times already. If, however, new and unforeseen circumstances arise, in which he cannot trust to his memory, he must act consciously. The result will be either adaptation to new conditions or annihilation.

What annihilation means is best shown by an example. A wheat grain passes into a hen's gizzard, that is, into quite unaccustomed surroundings. At first it thinks that it has been sown, and endeavours to germinate. Soon it becomes aware of the new conditions, becomes confused, and is ground up by the gizzard. The hen has brought the grain into such circumstances that its habits must overcome those of the grain. The grain is digested—that is, it loses its own individuality and partakes of that of the hen. It forgets its own past and becomes a part of the hen's past. Hence, when there is a fight to the death between two organisms, this means that the one is forced by the other into circumstances for which its predecessors had not yet prepared it.

It would take us too far afield to give further examples of Butler's ingenious use of analogy; the analogy between memory, and the likeness of children to their ancestors; between errors of memory and disorders of development; between the sudden remembrance of an experience long forgotten, and atavism; between the results of crossing, and the uncertainty of the man who sees in front of him two possible solutions of a problem. Butler considers that all the phenomena of heredity are merely exercises in memory. Variability he also explains psychologically. Organisms strive to fulfil their needs, as man strives for progress and invents and perfects machines to help him to attain his end. Human inventions often begin from some very trivial observation, of which no one can say at first whither it will lead. So organisms progress from small beginnings. They perfect their parts by constant use; they may even acquire new parts as the result of chance influences; they then work away at these new parts and so they develop them further. Natural selection is only of negative importance; it cuts off all unsuccessful attempts at progress.

Butler knew that his views were nearer to those of Lamarck and Erasmus Darwin than to those of Charles Darwin, and wrote a work to prove that Darwin's grand-

father, Lamarck, and Buffon, had given a better interpretation of evolution than had Darwin.

Butler's ideas met with approval from Wallace in England, and from Müller in Germany. But the psychological bias of his theories did not fit the spirit of the times, and his views were almost completely ignored.

Pauly, of Munich, has formulated (1905) a theory closely similar to that of Butler. He supposes that the organism, in its endeavour to realize its individual purpose, makes some new discovery. This new discovery exerts an influence on the next generation which will, therefore, attain to a greater or lesser degree of perfection, according as the discovery is advantageous or the reverse. The first sea-sponge that produced needles of silica to support its body made a less profitable invention than did the Tunicate which discovered the notochord. This notochord, used and perfected by the vertebrates in so many ways, was endowed with greater technical possibilities. The decendants of the notochordal creature perfected the organ step by step, until they arrived at that delicate mechanism, the human skeleton. So the first man who rubbed amber on his clothes was leading up to electrical science, though he could have no idea of all the electrical development that would result.

Pauly says that his theory is Lamarckianism, but in this he is mistaken. In his belief in the blind striving of the aspiring organism, he is nearer Darwin than Lamarck, as he is in his very utilitarian ideas about the organic world.

§ 5. *Hering and Semon.*

Before Butler, Ewald Hering, the physiologist, had pointed out an analogy between the development of body and of soul (1870). Butler looked upon this idea of similarity as a discovery—a new fact. Hering regarded it as a pure deduction from Fechner's theory, which affirms that our psychical and our material lives are two parallel aspects of one event.

According to Hering a stimulus causes a reaction in the organism, and leaves behind it some trace in the form of a permanent change in molecular constitution. Consequently, when the same stimulus recurs the reaction is somewhat altered. From the moment when it comes into existence an organism is continually exposed to the action of stimuli, and these all leave traces of their action in the inner structure of the organism. Each alters it in some slight degree. Hence we may look on the whole organism as the sum of all the material changes which it has undergone since the beginning of its existence. It is a principle of psychophysics that the objective side of subjective and conscious memory is a permanent change in the living substance as the result of a constantly repeated stimulation. On this view we may regard memory as the fundamental quality of the organism. All changes in mind and body are the results of this memory.

In the seventies Hering's theory aroused much discussion. It made no lasting impression, however, for it contained nothing new, but simply used the word 'memory' for the acquisition of new characters, nor did it consider any of the real problems either of mental or of material existence.

According to Hering's view, life consists merely of the passive repetition of all that has been learned, all that has been acquired. It teaches that imagination is but the sum of all memories, the organism merely the sum of all acquired characters. It ignores the most characteristic quality of the organism and of the soul—that the organism embodies some special idea, and that its mental images assume a special form. This idea, this form, are creations of the organism itself, and are not merely the result of a series of stimuli.

Hering's theory can easily be extended to include an hypothesis about evolution. This step was taken by Semon (1906), who endeavoured to save Darwinism by giving to it a psychological interpretation. He sought material analogies for such psychological conceptions as

thought, memory, experience, association, and so on. Following a bad modern fashion he began by giving these entities new names. *Mneme*—which is the title of his work—is to represent the sum of all those characteristics acquired by the organism and its ancestors; *engramm*, a single material change resulting from a stimulus. The words, are, in fact, no aid to the discussion. The work has been favourably received in Darwinian quarters.

Among the earlier biologists, von Reichenau asserted (1881) that evolution among living forms is to be regarded purely psychologically—as the effect of the action of will and of choice on the part of the animal; in his study of secondary sexual characters he suggested that Lamarck and Roux had sought to solve the problem of evolution along these lines.

§ 6. *Schopenhauer and Hartmann.*

Schopenhauer paid considerable attention to biological problems. His fundamental idea of the metaphysical will is closely related to the problems of instinct and so to those of biology. His works contain a curious mixture of facts, fantasies, and eccentricities. The philosophy of Schopenhauer is very closely related to Neo-Lamarckianism, in as far as that is a real philosophy and not merely a thoughtless reaction against Darwinism. What he has to say about 'will' in animals, about *Naturphilosophie* and science, about sexual life and so on, is still worth reading.

Schopenhauer himself spoke disparagingly of Darwin's theory. He also criticized the mechanistic tendency of Lamarck's views. With remarkable insight into the real inwardness of the problem, he repudiated phylogeny altogether, and, in contrast to it, upheld Geoffroy's idea of unity of plan.

Edward von Hartmann, who was a pupil of Schopenhauer, tried to show that there is an intimate connexion between philosophy and science, but he was not able even in this field to avoid the illogicalities characteristic of his

whole theory. Hartmann introduced the idea of the 'unconscious'; this represented Schopenhauer's 'will' plus 'idea'. He considered this the fundamental cause of all action. Starting from Man's conscious actions, he shows that, beyond the realm of consciousness, there are many other actions which do not differ from these in essence, and which, like the conscious ones, possess an ideal content. He points to the development of the embryo, to the healing of wounds, to the phenomena of instinct, to reflex actions; these are all analogous to Man's conscious actions, and yet are unconscious.

Hartmann partially agrees with the materialists, for he considers that the atom is the foundation of all reality; yet he assures those who believe in a soul that the psychic is not the result of the material, but is just as fundamental as is matter. He praises the endeavours of the scientists to get rid of such vague ideas as 'vital force' and 'life urge', for 'science should only seek for mechanical causes'. But the 'vital force' which he has banished from science he introduces into metaphysics, calling it 'will', and supposes that it controls all change. In regard to Darwinism, Hartmann's attitude was also one of attempted reconciliation between science and philosophy. He approved of Darwin's fundamental idea. He had a considerable knowledge of biological literature, and could follow the criticisms of a Kölliker, a Wigand, a Nägeli, and an Eimer. Aided by these, he formulated a very discerning criticism of Darwinism, totally rejecting the idea of a blind mechanism. 'The *struggle for existence* and *natural selection* are but labourers in the service of the idea. They perform the menial services in the realization of the idea, the shaping and fitting into place of the stones, which have been measured out by the Great Architect, and appropriately chosen for their destined place in His great building.'

Von Hartmann believes that the organism is governed by an inner law of development, a law of correlation. Natural selection, sexual selection, and so on, are merely so many external factors aiding this development. Teleo-

logy lays the foundation, and makes the mechanism possible.

Von Hartmann's biology was adversely criticized by the scientists; his metaphysics could hardly be favourably received by the Darwinists who considered that one of their greatest services had been to free the world of metaphysics. Schmidt, the Darwinist, and Wigand, the idealist, both found fault with his philosophy because it faced both ways. Displeased with these criticisms, Hartmann himself published an anonymous criticism of his own views, which was favourably commented upon by such Darwinists as Haeckel, Seidlitz, Schmidt, and du Prel.

§ 7. *Other Neo-Lamarckians.*

Many and varying theories are included under the name of Neo-Lamarckianism. The name is often applied to writers whose scientific achievements have been concerned with very different subject-matter, but who incidentally express themselves favourable to Lamarck's theory, in whole or in part. Thus some biologists are called Lamarckians simply because they hold that the function comes before the organ. Among these are the French physiologist Marey, and Roux, the originator of developmental mechanics. Others are called disciples of Lamarck merely because they have held that the organism possesses a direct power of adapting itself to its surroundings. Warming, Wettstein, Sachs, Pfeffer, Henslow, and Wagner, among botanists, Haacke, the zoologist, Roule, the embryologist, Roux, Rabl, and Semper, the anatomists, Koken and Jaeckel, the palaeontologists, belong to this group.

Another group have been called Lamarckians because they believe in the inheritance of acquired characters. Among these are Strasburger, Haeckel, Herbert Spencer, Brown-Sequard, Giard, Perrier, Packard, Semper, Kassowitz, Romanes, and others.

XXVI

GENETIC IDEAS IN BOTANY

IN his *History of the Inductive Sciences*, Whewell had already pointed out that, as the plant is comparatively simple in structure, the development of botany has always been more direct and less dramatic than that of zoology. Botanical theory has always been in advance of zoological. The zoologists, on the other hand, have, in the diversity of animal structure, a more varied material to consider. They therefore tend to imbue their theories with a deeper meaning and to investigate their significance more completely.

Systematic biology, for example, begins with Linnaeus's study of plants; Cuvier added to it by his study of animal anatomy. Morphology, as a theoretical science, began with Goethe's observations on metamorphosis among plants; it received a more plastic content from zoological considerations of analogy and homology. Schleiden, a botanist, introduced genetic philosophy into Germany; Haeckel, the zoologist, gave this both breadth and depth. The same phenomenon has repeated itself in the downfall of genetic ideas. Sachs, the botanist, was the first who called for experimental work; in the hands of Roux and Driesch the experimental method was raised to the dignity of a scientific philosophy.

The influence of Darwinism on botany was similar to its influence on zoology. It inspired botanical studies of the cell, and theories of invisible bodies in the protoplasm; mechanical explanations of cell division; theories of heredity, &c. The type of work that was being done in those times is indicated by the names of Wigand, Nägeli, Sachs, Celakovsky, and Strasburger.

Of these Wigand was the most conservative. He remained true to pre-Darwinian conceptions, and rejected the new ideas *a limine*. Celakovsky, always a morphologist, never entirely freed himself from the ideas of Braun and his school, but he accepted evolution. Strasburger believed in the new ideas whole-heartedly, and assisted in the working

out of new theories of the cell. Nägeli was a Darwinist, but he was in favour of a more physiological view of evolution, and in this Sachs agreed with him. Some botanists indulged in a great many phylogenetic speculations—Strasburger and Sachs, for example. Even to-day such discussions are in favour with some (e.g. Scott, the palaeobotanist), but they have never become as important in botany as in zoology. The botanists soon began to depart from orthodox Darwinism. We see this in their preference for the idea of the polyphyletic origin of plants, and also in the great importance they have attached to physiology. In the nineteenth century a deep rift developed between animal morphology and animal physiology. This rift was never so wide in botany, for the diversity of plant forms is not as striking or as characteristic as are the forms of animals; it is function rather than form that is of interest. The leaf of a dicotyledon is very similar to that of a monocotyledon or of a vascular cryptogam, and even among the mosses and algae structures occur which are very like leaves both structurally and functionally, and like them subserve assimilation, transpiration, and respiration. Among animals, on the other hand, function is subservient to form, as may be seen in the differences between the organs of locomotion in mammals, fishes, molluscs, echinoderms, medusae, and infusoria. In all these groups it is the form that stands forth. The form changes very strikingly from group to group, while the functions remain analogous.

This difference between animals and plants has determined the course of development of modern botany and of zoology. The effect of Darwinism was to turn zoology into a study of morphology, strongly tinged with phylogeny, a study of the parts of bodies to which definite functions were ascribed. Botanists, from the beginning, emphasized the fact that the physiological function determines the form. Sachs introduced this idea. He believed in the theory of evolution, but he was no upholder of the old academic morphology. With Schleiden and Nägeli

he was firmly convinced that the principal aim of scientific research should be to discover the causal connexions between phenomena. Following this idea out logically, he was less concerned with history than with the actual *cause* of structure, believing that this was partly due to internal organization, partly to the action of the environment on the plant. Sachs saw that the effect of the environment could be determined by experiment. Structures called forth by environment he called *Mechanomorphoses*; examples of these are the various leaf-like structures seen in the algae, the mosses, and in the higher plants. These are due to the action of light. Among mechanomorphoses von Sachs distinguished between 'photomorphoses', 'barymorphoses', and so on.

Other botanists followed the same line of thought as von Sachs, and endeavoured to determine by experiment how structures can vary as the result of alterations in the environment. Schwendener turned his attention to the mathematical view of spiral phyllotaxy (1878), and suggested that the spiral arrangement is due to the alternating pressure of the embryonic organs on the growing point. Vöchting succeeded in making the plant develop roots, leaves, scales, and other organs in predetermined positions. The results of these researches led him to attack both the preformation theory and the theory of the germ-plasm (1878). Pfeffer, the physiologist, evolved a system of plant physiology (1897) independently of Darwinism, on the basis of his ideas about energy and assimilation. Klebs and Goebel continued this experimental work. Goebel was the chief member of this non-morphological school; he even rejected the belief, retained by Sachs, that there are given inner organizations, and that adaptations are imposed upon these. Sachs regarded such an organization as something existing for itself, and quite independent of external influences; he quoted as examples of these heterospory and the seed habit. Goebel thought physiology all-important, and called his physiological botany 'Organography' (1898).

During the period when idealism was the popular philosophy, a contrast was drawn between morphology and physiology, the latter being the study of function, the former the study of form, which was independent of function. Goebel regarded this division as unnatural, since the structure always determines the function to a very large extent, while, on the other hand, function is constantly influencing structure. The plant is built up of organs—that is, of tools formed each for a definite task—which must be studied in relation to their functions. The Darwinists suggested that morphology should be included in physiology, but they did not follow up this suggestion; in practice they remained absorbed in morphology. Seeking always for the story of the evolution of plants, they were dominated by forms, which they arranged in evolutionary sequences. These phylogenetic trees do not explain why evolution thus progressed, but are rather like those series of abstract forms put together by the older morphologists though now held to represent the history of their evolution.

'We do not deny the importance of these questions of phylogeny,' wrote Goebel, 'but the results which have hitherto been obtained by the study of this subject are more like the products of poetic imagination than of an inquiry which calls for stringent proof' (1905).

Further, he does not doubt 'that the results of the older morphologists were based on a surer foundation than are the modern speculations about primitive forms'.

These were Goebel's reasons for introducing his new science of organography. Evolution remained his guiding star, but he did not deal with the history of the evolution of organisms; instead he discussed the origin and development of the various organs. His method is experimental, his aim the discovery of the immediate cause of the forms of organs.

Goebel explains his views as to the metamorphosis of the leaf thus. Goethe and his contemporaries thought that there exists some ideal of a leaf, some thought-out scheme. The various types of leaf—foliage leaves, stamens, petals,

scale leaves, &c.—are concrete manifestations of that ideal. Phylogenists arranged these forms in a series, which they regarded as having an historical significance; from the foliage leaf the petal, and later the stamen, had been evolved. Goebel himself does not believe in the existence of an 'ideal' of a leaf; all that exist are actual leaf forms. These resemble each other, not because they are embodiments of one general plan, nor because one has been evolved from the other, but because the one form can arise from the other here and now. The scale leaf which arises in place of the green foliage leaf in the maple tree is a leaf, for in early embryonic life it arises as does the foliage leaf. The effect of a change of function is that some parts of this leaf primordium are suppressed, while other parts develop. A type of leaf is thus produced, which resembles the other in broad outline, though differing in its detailed structure. From the same embryonic beginning very different structures may be developed. The cause of this difference is different function.

Thus Goebel enunciates a genetic view of living organisms, in place of a more formal one. He denies that morphology can be an independent science. 'By Morphology we mean', he writes, 'that which cannot yet be explained by physiology.'

Goebel's ideas are worthy of notice for several reasons. They express, in its most extreme form, that physiological conception which is so fashionable to-day. They represent the final working out of the idea first introduced by Darwin, that the form is the result of the manner of life. They are an absolute antithesis to the morphological point of view. Goebel's views are related to those of Aristotle, morphological ideas are nearer to those of Plato.

Finally, his phrase 'to understand physiologically' is interesting. With these words the Darwinists had dismissed everything that could not be explained but only described. While the Darwinists 'explained' everything by means of phylogeny and the mechanics of the atom, Goebel's explanations were always physiological.

XXVII

THE DOCTRINE OF INDIVIDUALITY

ONE of the most fundamental problems of biology is that of individuality. Leibniz pointed this out, and placed the individual as the indivisible and unchangeable *monad* in the centre of his system. Not without reason he contrasted his philosophy with the mechanistic philosophy of Descartes, and he attached great importance to the activity of living organisms.

From quite ancient times the idea of individuality has indeed been bound up very closely with the idea of the organism. There are, it is true, 'individua' in inorganic nature—things which are indivisible, which cannot be divided without altering their nature—as a stone, a molecule, a machine. Divided, these lose their original character—the stone loses its form, the molecule its chemical composition, the machine its usefulness. But the individuality of an organism is of a higher order; it reveals itself in its development, in the structure of its body, in its food, in its reaction to the influences of the external world, in psychical matters—in short, in the whole moving pageant of life. Further, the organism reproduces itself, i.e. it periodically repeats itself, and finally it consists of a hierarchy of more lowly individuals, intimately bound together. An earthworm represents a complete unit both in space and time; it has form and structure, is composed of heterogeneous parts put together according to a definite plan. Its development follows a definite sequence in time —it begins with the egg, passes through a series of forms, and finally dies. It is an individual. This individuality recurs periodically, for it lays eggs, from which new individuals arise. The earthworm is further composed of lower orders of individuals—of body segments, of organs, cells, &c. Finally, its individuality is manifested in its ability to avoid certain dangers, its ability to regenerate

lost body-parts, its power to co-ordinate its movements to a definite end.

In the early nineteenth century many morphologists dealt with this question of individuality. Alexander Braun (1849–50) ended his discussion of the problem of metamorphosis in plants thus: the simplest individual plant is the *cell*. This renews its youth by division, and may remain at the same level of individuality, or may raise itself to a higher level; in a Phanerogam, for example, it may form the shoot, i.e. a portion of the stem, with the leaves appertaining thereto. The individual plant is formed out of as many subordinate individuals as it has leaves. In some plants various stages in the individual life occur in definite sequence. The bean germinates, and from the seed there develops an individual with cotyledonary leaves; this gives rise to a series of 'foliage leaf' individuals; from the leaf axils a third series of individuals arises—the inflorescence axes and their bracts; these in turn produce the last and most highly developed individuals—the flowers.

Braun looked for some analogy in the animal world to this hierarchy of individuals in the plant world. He found it in the alternating generations discovered by Steenstrup (1842) among the Coelenterata. A free-swimming larva produces a coral-like colony, which represents the first stage in individuality, and from this are budded off free-swimming sexually mature Medusae (jelly-fish), as the second stage.

Leuckart (1851) attached importance to the analogy between plant metamorphosis and the structure of the Siphonophora. These latter have gelatinous bodies which consist of many less highly organized individuals, which are all formed on the same plan but very different in external appearance, for one is constructed for the taking in of food, another for reproduction, a third for movement, and so on.

Another idea arises from this study of individuality. Each organism is an individual, because its characters are specific; it is no mere aggregate of qualities; these

are so interdependent, that, given one, we can deduce all the others. Look at a cat, for example. Everything about it tells us that it is a nocturnal predatory animal which pounces on its prey—its eyes, its movable claws, its soft tread, its habits, which it reveals even when a kitten. The brain must be constructed to regulate its characteristic movements, the teeth to grasp its prey, the digestive system to assimilate a fleshy diet. Everything must work together harmoniously. We know, or at least we have some conception of, what gives point to the cat's whole harmonious organization. We guess, too, that the essential characteristic of the body of the swallow is the power of easy flight; that the structure of the whale's body is explained when we consider that it inhabits the sea. In other cases the essential character of an animal cannot be so easily visualized; nevertheless we see that every organism has a certain individuality. The giraffe seems to suggest length—by its whole body, by its head, its tongue, its neck, its feet, its curved back; the segmented insect has not only a segmented body, but segmented feet, segmented feelers—yes, even segmented eyes.

Considerations of this kind were very natural to pre-Darwinian science. Cuvier, Geoffroy, Goethe, Jussieu, and De Candolle expressed ideas similar to the above about animal form. Speculations of this nature were very commonly applied to Man; they called him an intelligent being, an ethical, religious, and social animal, and showed how much his intelligence had affected his bodily structure; for not only is his brain the servant of his intellect, but his hand, his foot, his eye, his upright position, all these are connected with his high destiny. Cuvier gave concrete expression to this idea of individuality. The fact that to each type of head there corresponds a special type of trunk, and to this again a special form of limb, he called 'correlation of form'. Following this conception, he deduced the structure of the whole body from single bones of extinct animals. Goethe and Geoffroy held very similar views.

The idea of individuality found no support in Darwinism; fundamental principles of that philosophy were, that natural objects only differ quantitatively from each other, and that each organism is merely the expression of the sum of its qualities. The essence of the conception of individuality, on the other hand, is that it is qualitative, and that the parts of each individual are pictured as woven together into a uniform whole.

Haeckel was in this respect still influenced by the older morphological conceptions, and he retained the word 'individuality' in biology—if not the idea. He was like the morphologists in that he only considered the individuality which is revealed by bodily structure. He certainly distinguished between the morphological and physiological individual. He defined the latter as 'a single organic body, occupying a definite volume, limited in all directions and indivisible'.

This might lead us to believe that he placed the physiological individual above the morphological. But the very fact that he seeks to define the nature of the physiological individual through its form shows that he attached much more importance to facts of structure, and we find that he did not investigate this physiological individuality further. His ideas about individuality were based on the facts of morphology, and he suggests that it presents the following stages. The cell, the organ, the *antimere* (a lateral organ of a bilaterally symmetrical body, as, for example, the hand, the left eye), the *metamere* (one segment of a body which is divided into segments lengthwise), the *person*, the *Cormus*. Of all these the only one that has any real claim to be called an individual is the single cell, and in recent times even its reputation for individuality has waned—together with that of atoms, protein molecules, and various hypothetical living 'units'.

There were many text-book discussions of this subject of individuality, but these had no real influence on biological thought. To-day the prevalent views on the subject are those of Haeckel. We follow him in presenting the

following degrees of individuality, although it is not possible to draw any sharp boundary between them.

1. Cells.

2. Multicellular organisms, which are subdivided into cell colonies, *coenocytia* and *metazoa*. The first include groups of cells, in which each cell is able to live independently and to produce a new colony, e. g. *Volvox*. The coenocytes are formed of groups of cells, in which the boundaries between the individual cells can no longer be traced. The Metazoa are multicellular organisms with definite internal structure, and showing cell differentiation.

3. *Persons* are formed either by the loose union of similar individuals (Corals) or the closer union of structurally different individuals (Siphonophora). Some philosophers make another group—societies—to include individuals of separate heredity who are held together by spiritual ties.

Tönnies distinguishes between communities when the individuals composing the group are descended from the same parents, and societies when this is not the case. Special cases of the union of several individuals are furnished by the phenomena of symbiosis. This is specially seen in lichens—plant individuals composed of two organisms only held together by their method of life; the organisms are an alga and a fungus, and each of these is capable of independent existence. Other examples are furnished by certain types of parasitism, where two individuals form one complete whole; and by a whole series of other phenomena, where two independent organisms of quite different origin adopt a mode of life which makes them dependent on one another.

The problem of segmentation, as seen in the body of the earthworm, claimed the attention of the evolutionary morphologists. Animals were divided into the unsegmented animals, like the worm ascaris and the mussel, in which no important part of the body is repeated, and the segmented; these were further subdivided into various groups:

(*a*) In some forms which otherwise show no trace of

segmentation one organ is repeated; this is seen in the worm *Gordius* and in *Chiton* (a gastropod). In the latter only the shell reveals segmentation, in the former it is seen in the nervous system. This type of segmentation is called *Pseudometamerism*.

(*b*) The body of the tape-worm is made up of many similar segments, all capable of independent life, and of a first segment called the head, which has a special structure unlike that of the others. Nevertheless, a series of such segments is required to form one tape-worm. This type of segmentation is called *Strobilation*. The name is derived from the strobilia—the larvae of certain Medusae. A cup-like larva divides, at right angles to its vertical axis, into segments which, having arisen by budding, become separated from the larva, and develop into free-swimming sexually-mature Medusae. In the tape-worm new segments are also formed by budding from the head.

(*c*) An example of true segmentation is exhibited by the annelid worms. In these the body consists of segments, each one of which forms a fairly complete unit, but there are a finite and definite number of such segments; in this respect these worms differ from the tape-worm.

(*d*) A still higher stage in metameric segmentation is seen in the differentiated (heteronymous) segmentation of insects. Head, thorax, and abdomen are formed from similar segments, but head segments differ from those of the thorax and these again from those of the abdomen.

(*e*) The highest stage of all is seen in the vertebrates. Their bodies are, it is true, segmented, as we may see in the backbone; yet the adult body forms so unified a whole that this segmentation is hardly noticeable.

Geoffroy and his school began to ask what is the meaning of this metameric segmentation. The followers of Darwin gave a genetic explanation; they asked which type of segmentation was the more primitive, which the more advanced, and then formulated their theory of its evolution. Some thought that metameric segmentation began in the Strobilia, others believed that the most primitive

type is seen in the pseudometamerism of the simpler worms. When Darwinian morphology became discredited the interest in this fascinating morphological problem vanished.

At the same time there was a revival of interest in the problem of organic individuality. If we concentrate our attention upon the purpose of the organism we are inevitably led to feel that it is harmonious, all its organs working together for one end. Studying the problem of regeneration we find that, within the fully formed organism, there is an active principle which is capable of renewing the structure that has been destroyed; and, when we turn to the philosophical question of the influence of the soul on structure and mode of life, we seem to see in the organism a unity which transcends the limits of time and space.

These new ideas of individuality reached their highest development in the theories of Driesch.[1]

[1] A philosophical analysis of the problem of individuality will be found in H. Driesch's *The Science and Philosophy of the Organism*, London, 1907–8, 2 vols.

XXVIII

SPECIES AND SUB-SPECIES AND THEIR USE IN CLASSIFICATION

§ 1. *General Conceptions.*

DARWIN'S attack on the constancy of species failed. Only his most faithful disciples—Haeckel, Schleiden, Schmidt, and Carpenter—accepted the suggestion that there are no species; Haeckel and Carpenter were the only workers who tried to follow up this idea practically, and in this they had no lasting success. The other Darwinists hold in theory that the word species does not correspond to any existing reality, but in practice they go on discovering new species, as was done in pre-Darwinian days. Buffon, attacking Linnaeus, said that there are no such things as 'natural' species or 'natural' families, nor any higher 'natural' groups; yet he treated of birds in one part of his book, and of mammals in another; he described horses in one article, donkeys in another! The Darwinists ask us to consider the facts of astronomy; it is probable that no star is absolutely still, nevertheless astronomers speak of fixed stars—those whose motion can hardly be detected; in the same manner, they point out, the variation in any species is usually so slight that we can afford to neglect it in practice.

The larger groups—orders, families, classes, &c.—have received less attention. The earlier belief that each organism exhibits definite characters defining its species, its natural order, and so on, was held to be untenable. If any one asserted the opposite view, as did Cope, his assertion passed unnoticed. Attention was concentrated on the nature of a species.

Of course, there *are* species in Nature. Any one who has once seen a domestic mouse, an apple, a man, would recognize these again. What, then, is the nature of a species? Linnaeus, to whom more than to any other we

owe the modern conception of a species, assumed that it consisted of an assemblage of external characters, such, for example, as size, colour, form, number of teeth, of stamens, and so on. His followers immersed themselves in the dull recounting of the specific characters of certain organisms.

Cuvier's idea of a species was more comprehensive. He regarded it as a group of anatomical characters which, taken together, gave us a fully defined unit. The triangle is not only a collection of sides and angles, it represents a definite unified whole. So, according to Cuvier, those features which characterize a definite group of animals, are in no wise 'disjecta membra'; combined, they blend harmoniously to form a single unit. Cuvier was an anatomist, and focussed his attention upon anatomical characters, though he did not deny that to define a species fully certain physiological ones were also necessary. Darwin and his school attacked Cuvier's idea of a species, but they, too, devoted their attention to anatomical characters, and returned to the ideas of Linnaeus, with whom they agreed that the species is represented by the sum of its characters.

And yet a species is not fully described by enumerating its specific characters, nor is it sufficient merely to note anatomical characters. Habits of life tend to be constant, not only through a species, but through wider groups. Such names as predatory animals, birds of prey, hyaenas, nightingales, owls, do not merely suggest animals of such-and-such bodily characters; they remind us that predatory animals, for example, are flesh-eaters (though the cats, the dog-like animals, the hyaenas, hunt their prey in a diverse manner); owls are night-flying birds; nightingales are good singers; ants are not merely characterized by the veins in their wings, and by the protuberances on each segment of the body; a further characteristic is their very highly specialized social life.

Yes—even such an elusive character as the numerical relationship between the sexes is constant, and so becomes a characteristic typical of the species. Further, it is the

union in one organism of these characters, not the mere fact that there is a series of them, that defines the species. The species lion, for example, expresses an ideal unity, although it is an actual existent (just as a quadrilateral, or gravitation, are abstractions, although real). It is a unity composed of physiological, embryological, psychological, and other characters. This does not exhaust the peculiarity of this idea of a species. One characteristic of the conception—and this is true of the whole world of living organisms—is that the species cannot be fully realized from one individual. A male and a female, a caterpillar and a butterfly, several strains, and so on—these constitute species.

§ 2. *Sex.*

Philosophers have sought in vain for any other phenomenon, either in the living or in the non-living world, comparable to the relationship between the male and the female. Each sex seems to be, in body, in function, in soul, a finished whole, and yet only together do they form a really complete unit.

The following degrees of sexual differentiation are to be distinguished:

(*a*) Asexual organisms; to this group belong certain fungi, all bacteria, and some algae.

(*b*) Organisms in which the sexual differentiation is only physiological. Two organisms which are apparently absolutely identical unite for reproduction. Good examples are provided by the protozoa. In other cases the differences between the male and female cells are sometimes visible to the eye, as in some algae.

By far the most numerous are organisms with a definite sexual reproduction. These are either hermaphrodites, or they consist of two separate sexes.

(*c*) Hermaphrodites are often so constructed that they can be either self-fertilized or cross-fertilized. The cleistogamous flowers of many plants are always self-fertilized.

These are small flowers which never open, and which occur in addition to the ordinary flowers.

(*d*) Some hermaphrodites contain the organs of both sexes, and yet two individuals unite for fertilization. This is the case in most of the phanerogamic flowers, where the pollen of one blossom is carried to the pistil of another. In hermaphrodite animals cross-fertilization is apparently the rule; self-fertilization only occurs when a cross is impossible.

(*e*) There are some hermaphrodites which possess the organs of both sexes, and yet are so highly differentiated that the male organs of one individual only fit the female organs of *some* of their kind, and vice versa. In the primroses, for example, there are two types of flower; in the one (called 'thrum-eyes') the stamens are above the stigma; in the other ('pin-eyed') the positions are reversed. Fertilization leads to the best results, when pollen from the shorter stamens is deposited on the shorter pistil, and that from the longer stamens on the longer pistil. Other arrangements occur which necessitate cross-fertilization even among hermaphrodites; for example, one of the sexual products (either the male or the female) may be ripe before the other. In the Lime the stamens ripen in every flower before the pistil; in Aristolochia the reverse is the case. Analogous phenomena are seen among the Molluscs and the Tunicates.

(*f*) Darwin discovered that some hermaphrodite Cirripedes (small fixed Crustacea) produce, in addition to the normal form, small parasitic males; a similar relationship obtains among the Myzostomata, a peculiar group of worms. Many plants bear, in addition to perfect flowers, others which only have stamens (e.g. *Gallium cruciatum*) or only pistils (e.g. *Orache*).

(*g*) Finally, there are the organisms in which the sexes are quite distinct. They complete each other, not only in the structure and function of their sex organs, but also in temperament. The male is active, aggressive, mobile, and seeks the more passive female. This fundamental difference

may go further, and male and female may differ in the so-called secondary sexual characters also—that is, in characters other than those serving the actual act of fertilization. As examples of these we may cite the beard, the greater hairiness and strength of the man, and many similar features. Males tend to have more perfect organs of sense and of locomotion, to have more brightly coloured feathers, to possess antlers and other adornments. They are better singers, emit peculiar odours—animal beauty, in fact, often depends on the special development of these secondary characters. The flowers of dioecious and of monoecious plants are often distinguishable by characters other than those of the reproductive organs. In Catasetum, among the orchids, the flowers—which look like a Medusa's head—are so different that they were thought to belong to three different species: at one time the male was called Catasetum, the female Monachanthus, the hermaphrodite flower Myanthus.

Sex, then, usually expresses itself in the existence of two individuals, often very different in their appearance and in their mode of life; but when we have stated this fact we have by no means exhausted the phenomena of sex.

(*h*) Among the social insects—bees, ants, and termites—only a few individuals are sexually developed. Others—the worker bees, for example—possess degenerate reproductive organs and are different in appearance from the perfect individuals. Sometimes three or more different types of individual exist. Among bees there are three types. Forel (1904) describes ten different types in certain ant societies, and all these forms belong to one species.

(*i*) Among certain insects the one sex has one form only, the other two different forms. There is one form of the male butterfly—Papilio merope—but several types of female. Some species of wasp (certain of the Chalcididae) have one type of female, but two different kinds of male.

(*j*) Finally, we must point out the remarkable fact that, for each species, the numerical ratio of males to females is a constant one.

The nature of sex has not often been the subject of phylogenetic discussion. Darwin himself directed his attention entirely to the secondary sexual characters, and Darwinian speculations concerning origins were concerned only with these.

In connexion with the question of the meaning of sex, it is often asked whether the male or the female is more highly developed. As is well known, Aristotle asserted that the female is a lower type than the male. Darwin (*Descent of Man*) also thought that, as a rule, the female is the less developed, and many share this view with him. Von Kennel asserted that the female represents a degenerate type—the ovaries need much nourishment, and so the growth of other organs is adversely affected. Only a few workers have held the opposite view. Montgomery was among these; he supported his ideas by the following arguments:

(i) Males are more often completely degenerate than are females, e.g. the males of Rotifera, of the worm *Bonellia*, of the Cirripedes. Females, as a rule, only have some organs abortive, e.g. the females of some insects have abortive wings.

(ii) Hermaphrodites are usually protandrous, i.e. the sperms mature earlier—and hence at a lower stage of development—than the eggs.

(iii) In most invertebrate animals the females are longer-lived, are larger, have more complicated sexual organs, and are entrusted with the care of the new generation. This must be regarded as a higher state of development, in spite of the fact that the male has more perfect organs of sense for locomotion and copulation. Among vertebrates the males have, as a rule, a simpler urino-genital duct, the females having separate ducts. In comparison with these facts the secondary sexual characters are unimportant, for, according to most phylogenetic theories, they are of more recent date.

Most naturalists, then, have held that the male is the more highly developed form; only a few have raised their

voices in favour of the opposite view. The supporters of feminine emancipation, however, have turned even to biology to find support for their assertion that the female is intellectually the equal of the male.

§ 3. *Polymorphism.*

Man is first an egg-cell, then embryo, infant, youth, man, and old man, and the name 'human being' does not apply to one of these stages only, it applies to all. These manifold forms, developing in course of time, are characteristic of the living organism. It is true that water can be now hot, now cold, now in drops, now as snow, ice, vapour—but there is no unchanging sequence; it may alter its state, but is not bound to do so; further, the alteration may occur in two directions. An animal can neither remain at the same stage of development, nor can it go backwards. An organism, then, develops as a series of forms following one another in time—the one passing into the other. Sometimes certain stages in this series are so complete in themselves, that they form a rounded whole; the whole life is then like a chain, consisting of a series of links, each one obviously more or less complete in itself.

Even among human beings this is just suggested, for the embryo 'in utero' leads a life very sharply marked off from its independent life as an infant. The following cases of metamorphosis during development are the ones usually quoted:

(*a*) Development without metamorphosis; among the lizards the embryo develops within the egg, and when it escapes it resembles the adult, although it is small.

(*b*) Development with metamorphosis, as is seen in the frog. The embryo becomes a tadpole, which lives in water; this then changes into the frog, which differs from the tadpole both in structure and in its way of life.

(*c*) When there is alternation of generations two phases of the life history alternate; these do not pass into one

another by metamorphosis; each phase is borne by the other, and begins as a single cell. This mode of life is well seen in mosses and in the higher cryptogams. In the fern, for example, the asexual fern lives and reproduces as an organism complete in itself. After a certain period, or under certain external conditions, it forms spores; from one of these there develops the sexual plant, which is quite different in appearance from its immediate predecessor. This forms eggs and sperms, and after fertilization, asexual plants develop from the eggs.

There is a certain resemblance between this mode of life and that seen among the infusorians. These reproduce for many generations asexually by fission, but eventually a sexual copulation between two individuals is necessary to stimulate to renewed activity. Among the lower plants sexual and asexual generations may alternate according to varying laws.

(*d*) Heterogony is the name given to that type of alternation in which each generation is sexual. The parasitic worm which lives in the lungs of the frog (Rhabdonema) gives birth after fertilization to larvae, which in their turn come to possess fully developed sexual reproductive organs; from these the original form is once more produced. Heterogony is often seen in parasitic worms.

(*e*) A sexual generation may alternate with a parthenogenetic one, (by the latter term we indicate embryos that develop from unfertilized eggs). In summer the Aphis only produces females and these reproduce parthenogenetically. In autumn males arise as well; they fertilize the late females, who then lay eggs from which, in spring, a new generation of females arises, to continue the story in that year. In this case the parthenogenetic generations are more numerous than the sexual ones; sometimes the sexual form is very rare and can even be completely suppressed (latent). Some forms of Aphis, some wasps belonging to the Cynipidae, some Rotifers, certain small Crustacea belonging to the orders Cladocera and Ostracoda, only reproduce parthenogenetically. Among plants

there are certain ferns in which the sexual generation is in abeyance—they reproduce by means of spores, which begin to grow apogamously while still on the leaves.

§ 4. *Subdivisions smaller than the Species.*

Before the time of Linnaeus, Leibniz had discussed the differences between the individuals of a species. He pointed out that no two things in the world are absolutely identical, since then it would be impossible to distinguish between them. This view divided his followers into two camps; the one group, the more practically-minded, were convinced from their every-day experience that there are natural groups of organisms (Tournefort stressed species, Linnaeus orders); for them Leibnitz's formula meant that every order, every species, passes over into many others. Another group, including Lamarck, preferred Bonnet's more abstract teaching, and interpreted this idea differently. They believed that all organic beings can be arranged in a single series, in which each individual represents a transition between the two others standing next to it in the series, and only between these.

While morphological ideas prevailed, the first of these views was the more generally accepted one. In the early nineteenth century the Swiss morphologist Pyrame De Candolle turned his attention to the question of species. He began by considering a fact already known to Linnaeus, that a chance departure from type may prevent us from recognizing a member of a known species, and that such chance departures may be due to the influence of the environment.

To eliminate the influence of such chance irregularities upon our definition of the species, he called for experiments to determine the nature of each species. To describe one or a few individuals is not enough—it is impossible to say which characters are constant, and which fluctuating; each type must be under observation for several successive generations and while exposed to very different conditions. Then, in defining the species, we

must only take into consideration characters which remain constant under these conditions. These ideas of De Candolle represented a great advance upon merely descriptive methods of defining a species. But the whole discussion was soon turned into new channels.

In the nineteenth century mere classification still flourished in England. Darwin knew little of continental morphology, and his work obviously followed the prevailing English ideas. From the discussions of scientists whose somewhat stale ideas were based chiefly on herbarium material, he inferred that individual and chance variations often represent the beginnings of new species. Thus he turned men's minds back to the ideas of Bonnet, Buffon, and Lamarck.

In discussing variability Darwin distinguished between individual differences and more strongly marked variations; he called the latter 'single variations', as when a three-toed horse is born. At first Darwin did not say which type of variation he considered the more important for the origin of species. Later it was pointed out that the strongly marked 'single variations' are of very rare occurrence, and that they must necessarily disappear very soon, since they mate with the typical form. Darwin then admitted that they must be less important than are individual fluctuations, as starting-points of new species.

In the early discussions which ranged round the idea of evolution Darwin's reasoning and deductions were merely repeated; when the first enthusiasm had waned workers turned their attention to his assumptions, and endeavoured to check them and to widen them; and, as this work progressed, interest in his theories diminished. Observations made by Nägeli, Kerner, and Hoffmann now attracted attention; their views on variation were rather different from those of Darwin. They believed that variations due to the action of the environment, and non-inheritable, are fundamentally different from those inheritable variations which make their appearance as the result of the action of internal causes.

Weismann, in his theoretical discussions, drew a similar distinction between the two types of variation. There was, too, a revival of interest in the views of De Candolle. In France, positivism was flourishing; this philosophy suited the analytical gifts of the French intellect, and served to unite the views of Cuvier and of Lamarck. It led to the abandonment of any endeavour to settle these questions by experimental methods.

Just at the time when Darwin was studying domestic varieties, endeavouring to prove that they resemble natural varieties, and may be regarded as the beginnings of new species, the problem of the relation between races and species was being once more discussed in France too.

Quatrefages treated the question from the anthropological point of view, Godron from the zoological, Naudin and Jordan from the point of view of botany. All these workers assumed that species actually exist, and their research was directed to the finding of an exact method of defining the same.

Jordan, a botanist, collected species of *Draba verna*—a common weed of dry meadows—from all parts of Europe and cultivated its varieties for several successive generations, as De Candolle had advised. He found that this single species includes over two hundred constant and unchanging varieties; he declared that all these must be regarded as minor species within the larger one. He held that these constant varieties must be distinguished from those artificial ones which revert to the ancestral form in a few generations if left to themselves, as do, for example, the varieties among cultivated fruit trees (1873).

Godron held similar views. His book *On Species and Races* appeared in the same year as Darwin's great work; the views there expressed are opposed to those of Darwin. He affirms that wild races, living in a state of nature, are quite constant and sharply distinguished from one another; variations only arise occasionally, and they are not maintained. Domesticated races form a contrast to these; they have been bred under artificial conditions, and

have undergone modifications which are transmitted by heredity.

Naudin (1865) seems to favour the opposite view. He considers that there is no essential difference between a species, a family, and a variety. Experiments led him to consider that a species is 'a group of individuals which resemble one another, and differ from all other groups in greater or less degree, and which retain the same physiognomy and organization through many successive generations'.

The difference between Naudin and Godron is, however, only a difference in the use of the words 'species' and 'variety'. Naudin assumes that there is evolution of new forms, as does Lamarck; but in practice he is fully convinced of the constancy of those characters which define the species, and he believes that new forms represent some new combination of such characters. Such new combinations are due to crossing, and they do not mean that there has been any fusion of the specific characters, only a resorting of the same.

The French experimental work was for a time superseded by Darwinism. Darwin and his followers looked upon such work merely as an attempt to find experimental support for Cuvier's definition of a species, and Cuvier had said that a cross between two different species could not produce fertile offspring. There was, however, to be a return to his ideas later.

Among evolutionary theorists the idea that new species arise by saltations from previously existing ones was continually being discussed. Bateson, in the introduction to his *Materials for the Study of Variation* (1894), has shown us how this hypothesis developed out of Darwin's views. He describes how enthusiastically Darwin's ideas were accepted, how constantly biologists discussed these questions of heredity and of adaptation, how work on anatomy or embryology was always directed to the finding of new facts which would support Darwin's theory, and how indiscriminate the enthusiasm aroused by the theory was.

Bateson wrote to free men of science from this obsession. Although he did not know it, his thought is directly connected with those earlier ideas of the nature of a species which were rudely interrupted by the advent of Darwinism. He abandoned Darwin's main thesis, that there are connecting links between all species, and taught once more that there are definite gaps in nature's vast diversity of forms. The environment is too uniform to have been the agent which produced this great variety. New species originate suddenly—and the sudden appearance of new characters is a much less rare phenomenon than is commonly supposed. Bateson's work is chiefly concerned with the collecting and classifying of these 'discontinuous variations', as he calls them.

Bateson had no intention of challenging Darwin's fundamental assertions. He did not realize that his point of view was directly opposed to that of Darwin, and that his theories represent a return to the earlier belief, that species are something more than 'aggregates of convenience' of similar forms.

Later workers who followed similar lines of investigation were also quite unconscious of this antagonism. Korschinsky's botanical work resembled that of Bateson in zoology. In 1899 and again in 1901 he pointed out how often, in practical gardening, new forms suddenly arise and then remain constant. The common Acacia has given rise to the following new varieties quite suddenly and without any obvious reason. In 1833 a form without thorns; in 1855 one with simple leaves; in 1862 one with pink blossoms, in 1862 also a form which is a very profuse and early bloomer. The double petunia arose in 1853; *Cyclamen persicum* has been grown as a garden plant since 1731, the double form only appeared, however, in 1850.

From these, and many other similar instances, Korschinsky deduced that species have not arisen by any gradual process such as Darwin believed in, but by occasional sudden changes; he called this method of production 'heterogenesis'. In all other respects his views

agreed with those of Nägeli, and he believed in a principle of perfection.

De Vries investigated the subject of discontinuous variations, or 'mutations'. While Bateson and Korschinsky took their data from books, De Vries attacked the problem experimentally. In his fundamental ideas he was in agreement with the French school—with the work of Jordan on the one hand, and of Nägeli on the other. He drew a sharp dividing line between artificially produced species—in which fluctuating variations are accumulated by artificial selection—and natural species which arise by mutation. The amount of sugar in the beetroot, the juiciness of the carrot root, are examples of fluctuating variations; these have been increased by cultivation, and are passed on by heredity, but disappear directly the plant reverts to wildness. Mutations—deviations from the parent species which appear suddenly and without any obvious cause—are quite different in their behaviour. They 'breed true', and hand on their special peculiarities from generation to generation.

In the year 1886 De Vries began to study the mutations of the American plant *Oenothera lamarckiana* (Evening Primrose). He obtained a whole series of mutants from the parent form, e.g. *O. gigas*, which has broader leaves and sepals, the foliage leaves more curled, while the fruits are shorter and contain fewer but larger seeds than do the fruits of the parent form. These mutations were regarded by De Vries as constituting 'elementary species', and, according to him, such mutations or saltations represent the first steps in the formation of new species. The struggle for existence destroys those that are valueless, while those that survive give rise to fresh mutations, and so the variety of living forms has been produced.

Many Darwinists accepted De Vries' theory, but it has also been subjected to considerable criticism. De Vries observed that the same mutant may arise in different ways —not from the parent form only, but also from other mutants. His critics pointed out that these changes may

simply be developments of latent characters, and not advances towards a new type.

Though with less justification perhaps, there were others who did not admit that there is any really fundamental difference between fluctuating variations and mutations. There were philosophical objections as well. Driesch and Whitmann have rightly pointed out that we cannot reconcile our ideas of a reign of universal law in the organic world, with this assumption that spontaneous and purposeless mutations may occur.

Some workers tried to reconcile the views of De Vries and Darwin; Keller for example, suggested that our various races of domestic animals have sometimes arisen by the selection of fluctations (e. g. the Simmenthal cattle), sometimes by sudden mutations (Dachshund). The true Darwinian point of view however—even his view of evolution —bore only a very superficial resemblance to the views of De Vries; the two theories are really fundamentally different.

Beginning with a discussion of the idea of 'elementary species', the analysis of this idea of 'species' has been carried still further. The individuals of each elementary species and of each mutant are not all alike. If two individuals pair, their offspring will have some of the paternal and some of the maternal characters; and since the parents are not identical, their characters will be differently combined in their children.

Some plants and animals are self-fertilized. In these the characters of the individual remain constant throughout any one series which is the result of self-fertilization.

Johannsen (1903, 1909) succeeded in separating two such series in a bean (*Phaseolus vulgaris*—'princesse') which is always self-pollinated. He divided the seeds produced by the plants of one bed into three groups, according to their size, and planted each group separately. He divided the seeds of the second generation in the same manner. After several generations he obtained from the small seeds plants which only bore small seeds, from the large seeds

plants which bore large seeds only. The original bed must have contained a mixture of forms; if we call this group of forms a 'population', as Johannsen did, they must have been the product of at least two ancestral forms, as the above experiments show. Johannsen called these two ancestral forms 'pure lines'. The beans were self-pollinated, and hence these two strains ran parallel to one another. Similar 'pure lines' exist in other forms, but owing to the necessary crossing of two individuals which sexual reproduction entails they become obliterated. This idea of pure strains forms a strange conclusion to Darwin's theory of species. It is much more characteristic of the biological thought of the day than is the Darwinian conception of species as merely artificially determined groups.

De Candolle regarded a species as an intellectual abstraction from some group of forms that happen to be under examination. Darwin, on the other hand, looked upon it as a tree in whose stem all branches flow together towards a common root. Johannsen suggested a theory which linked up the formal and the genetic ideas. A species consists of a stream of similar forms which run a parallel course in evolution.

§ 5. *Statistics relating to Variation.*

The differences between some species are so minute that they are often less obvious than are chance fluctuations due to the action of the environment. Quetelet and Francis Galton introduced the statistical method into biology, in order to find the middle value in a series of varying forms. This now forms an important branch of applied mathematics, into the details of which we shall not enter; we will merely illustrate its use by a few selected examples.

The beans produced by any garden bed differ in size—the differences being due to inner and also to chance external causes. If we separate these beans into groups

according to their length, and arrange them in a series of glass tubes so that the longest are placed in the first tube, the next sized in the second, and so on, the upper surfaces of these bean columns will form a so-called 'Gaussian curve of error', or normal curve. Beans of medium size will be the most numerous, the largest and smallest sizes will be the rarest; from the maximum point the heights of the columns will diminish symmetrically towards both ends of the curve.

From this we deduce that there is an average value which all beans tend to attain. External factors, however, cause some to become larger than the average, others smaller, and, since the variation curve is symmetrical, we conclude that the factors making for largeness are, on the whole, equal in potency to those making for smallness.

Some cases are more complex. We might, instead of the size of beans, consider the number of axes in an umbel—this number is also variable. From among a large number of plants we would group together those with six, those with seven axes, and so on, and we should find, as before, that there is an optimum number which occurs in the greatest number of specimens. The final result might, however, be different from that obtained from the study of beans.

Ludwig obtained the following results from studying the axes of the first order in the umbel of *Torilis anthriscus*:

	5	6	7	*8*	9	*10*	11	12	13	14	15	16	axes
in	4	27	45	*135*	108	*117*	72	17	9	3	3	1	individuals.

The maximum value is not the middle value but there are rather two maxima, namely at eight axes and at ten. The reason for this was that here two forms were growing together which differed from each other in the average number of axes. Ludwig eventually found these forms growing separately in other districts, and when he investigated the number of axes statistically he obtained the following results. In one place

No. of axes	5	6	7	*8*	9	10	11	12	13
No. of individuals with this no. of axes	1	11	18	*45*	28	20	5	4	1

and in the other

No. of axes	5	6	7	8	9	10	11	12	13
No. of individuals	–	1	5	8	13	25	12	5	2

This example illustrates the importance of the statistical study of variation. No analysis of the characters of one or of a few individuals gives us a complete and comprehensive view of the nature of any type. A statistical examination of a large number of forms will render obvious the existence of certain boundaries which other methods do not reveal.

Following Johannsen, species and varieties which have been statistically defined are called *Phaenotypes*, for their properties are determined by their external features only, and no assumption is made as to whether these features are inherited or no. Johannsen distinguishes between these and *Genes*—such elements, tendencies, and conditions as are determined by the reproductive cells. It is suggested that each reproductive cell contains a series of genes, i.e. of the rudiments determining characters. The discovery of these genotypically determined characters becomes the task of the Mendelian worker; he uses Mendelian methods of crossing and of pure breeding; such discoveries are among the most widely discussed problems of modern experimental biology.

For a long time one criticism of Darwinism has been that there is no such gradual variation as he postulated—things vary round a mean value. Statistical methods give new support to this assertion. It is possible, by artificial selection, to cause some change in this mean value, but the alteration cannot be carried beyond a certain point, and if the artificial selection ceases, the things revert to the original mean value.

Finally, we may mention that problem so often referred to by the Darwinists—Does variation occur within the same limits among both the higher and the lower forms? This has, up to the present time, only been discussed in very general terms. Many investigators have assumed that the lowest forms, and the forms found in the oldest strata of the earth's crust, show more tendency to variation than

do the higher, more recently evolved types. They point out the greater complexity of the more highly organized types, and assume that this must restrict their variability within narrow limits. G. Seidlitz, Daniele Rosa, and others held this view.

§ 6. *Physiological Species.*

Until recent times there was a fairly general conviction that species are simply groups defined by anatomical characters, and that their physiological and biological properties are the result of their structure. This view was held in spite of the fact that Lamarckianism, Vitalism, and the Darwinian theory were fundamentally opposed to any such assumption. Lamarck declared that the animal's own efforts lead to the formation of new organs; the vitalists regarded function as higher than form; while it was the fundamental hypothesis of Darwin that the conditions of life determine the form of the organism. Yet such was the strength of the old anatomical ideas, that none sought to define a species by any other than morphological characters.

Nevertheless organisms do show physiological specificity. When we speak of a blood-relationship between animals we no longer mean merely a genealogical relationship. Landois in his day carried out some interesting experiments, and these have been repeated more recently under different conditions by H. Friedental, G. Nuttall, and others. They were designed to prove that human blood is chemically more like the blood of the anthropoid ape than of any other animal.

These experiments were cited as affording a new proof of the Darwinian theory. Even the budding and grafting of trees, and of animals, where these processes can be successfully carried out, depends upon a near physiological relationship; it is only possible between nearly related forms. From such experiments it should eventually be possible to discover physiological affinities and relationships between living organisms. Before this can be done,

however, the problem will require considerable investigation, that we may see how far physiological affinity corresponds to anatomical relationship. The idea that organisms may be physiologically related leads us to the idea of physiological species.

The well-known wheat rust (*Puccinia graminis*) exhibits in its life history a peculiar alternation of generations. In its first phase it is a parasite living on the leaves of barberry and forming spores (called *aecidiospores*). If these are carried to a grass they grow and produce patches of rust; the reproductive bodies of these plants are summer spores (*uredospores*); these produce rust on other grasses; finally, in autumn, winter spores (*teleutospores*) are formed.

J. Ericksson (1884) proved that in this rust fungus six species may be distinguished. These are anatomically alike and are only to be recognized physiologically. The one, the uredospores formed on the oat, for example, will only infect this grass and one or two other species; it will not infect wheat, while the wheat rust can only germinate on wheat and not on oats. Ericksson called these species 'biological species'; others have called them 'physiological species', 'species sorores', 'formae speciales', 'Gewohnheitsrassen'.

Similar facts are known about parasitic animals. The worm *Tylenchus scandens*, when it had lived for several generations on grasses, lost the ability to live on bulbous plants. The aphis *Chermes strobilobius* is anatomically practically identical with *Chermes lapponicus var. praecox*; the two can only be distinguished by their mode of life.

These observations merely represent a tentative effort to prove that genera and species can and must be defined by their physiological, biological, and psychological characteristics, and not by their anatomical characters only. Agassiz had already put forward this suggestion, but his opponents had found it unacceptable.

We may close with a suggestion. The biological species *Tylenchus scandens* is defined by the fact that this worm has weaned itself from a diet of onions. No one has objected

to the establishment of a new species on these grounds! Yet what scorn would be poured on any investigator who should suggest that the morality, the religious sense, or the intelligence of man could be used as a basis of classification to divide mankind into separate classes!

§ 7. *Variability regarded as the Result of the Influence of Environment on the Organism.*

The question of the relation between the organism and its environment is not entirely *modern*. It has been one of the main themes of philosophy since the time of Locke and Leibniz. Hume and Kant began with the same problem in working out their systems, but they were concerned not with organisms in general, but with one special organ—the soul of man—as were the later philosophers. Leibniz propounded the thesis that the surroundings do not influence the soul; it develops as the result of its innate tendencies, which are there from the beginning. It receives nothing from its environment, nor can it influence that environment. The surroundings have no power over the organism; it runs its own course, and in it the surroundings are, as it were, mirrored, but they do not alter it in the slightest degree. Locke took the opposite view that the environment has the power to store up experiences in the soul, and so, in this way, to change the nature of that soul. Hume attached still greater importance to the influence of the outer world upon man. Like the modern theorists, who declare that the organism is nothing but an accumulation of sense-impressions, he looked upon the soul of man as a mere bundle of sensuous experiences. Kant sought to bridge the division between Leibniz and Hume. It is true that he recognized the significance of experience, but he held that the soul has the power to determine in what way its surroundings shall influence it. Modern biology is still quite unable to solve this problem; it sees on the one hand the active individual, which feels itself to be independent of the world around it; on the other hand there

is the environment, which seems to be continually acting upon that individual. What is the connexion between the two?

It is obvious that the organism is dependent to a certain extent upon its surroundings. But there is still this question to be answered: do any of these influences alter the essential nature of the organism, or are all the changes brought about by the environment, merely casual and superficial modifications of an individuality which in itself does not change? Most modern biologists seem to be of the opinion that the surroundings (i.e. Nurture) are capable of actually moulding the Nature of animals and plants. Unfortunately, however, this opinion does not represent an idea which has been arrived at by any process of independent reasoning; it has sprung from the tendency to 'explain' the evolution of species by referring to the inheritance of acquired characters. Had not this tendency given a certain bias to the observations of scientists, who knows if they would have held so tenaciously to this realist doctrine?

To Darwin and his followers the problem presented no difficulties, for they did not think of the organism as a spiritual entity. The plant, the animal, or the man, was for them merely an accumulation of modifications acquired by chance. Each such accumulation increases throughout the whole individual life and is passed on to the descendants. Darwin's views on variability depended on his conception of the organism. He looked upon it as a mere passive agent, exposed to the influence of a varying environment. Hence for him there was no appreciable difference between a mutilation, by which the organism quite passively suffers a change in bodily form, and an inborn variation.

Weismann, in his discussion of this problem, emphasized this difference. He thought that inherited variations are due to forces residing within the organism, while acquired ones are due to the action of the environment. Darwin's original assumption that there is no essential difference between the two is, however, still upheld. Thinkers of

this school will not admit that inborn variations represent something absolute, and not traceable to external causes; but they regard these variations too, as brought about by the influence of the environment; in these cases the influence of 'Nurture' upon the organism must be more profound, however, and the connexion between this 'Nurture' and the resulting change in the 'Nature' of the organism must be more complicated.

The mechanistic conceptions of nineteenth-century biologists led them to recognize quantitative variations only. It is true that they distinguished between variations which affect the form (changes in size, colour, shape, bodily proportions, the number of limbs, and so on); those which affect the function (as when, for example, an animal becomes accustomed to new food); those causing mental changes (e.g. training); but they traced back all these modifications of the organism to displacements of certain substances in the egg, in the alimentary canal, or in the brain; displacements which, small in themselves, led to much greater changes in the mature organism.

These views are apparently in the process of decline to-day; in vain do we strive to bring Darwin's original assumptions, that the organism is absolutely passive in its reaction to the influences of environment, and that the resulting variation is quantitatively proportional to the cause, into harmony with the facts. Vainly we try, by various subtleties of argument, to avoid admitting that the organism is an active 'self-controlling' agent.

It hardly occurs to any one now to place a mutilation, or an increase in weight which is the result of better nourishment, in the same category as changes like seasonal dimorphism, although we speak, in all these cases, of the action of the environment.

Passive changes are not considered in our theoretical discussions. The active reactions of the organism to the influences of the environment are classified in various ways. They can be divided empirically into morphological, physiological, and psychological reactions. The morpho-

logical ones can again be split up into different classes. Instead of giving a further classification, we will quote a few examples. Under variations due to habitat have been included (by Nägeli and others) such small modifications in plant form as are brought about by differences in climate, in light, in intensity, in humidity, &c. Thus the common knotgrass (*Polygonum amphibium*) appears in three varieties, a land form, a water form, and a sand-dune form. These differ from each other in the structure of the stem, in the shape of the leaves, and in their hairiness. The differences are to be regarded as the reaction of one and the same plant to different environments; for by changing the amount of moisture we can change the water form into the land form or the sand-dune form. Zoologists introduced the name 'local varieties' for these minor differences in form. Almost every species which extends over a wide area has several local varieties. Thus the common goldfinch (*Carduelis carduelis*) exhibits the following forms: mountain goldfinches are always larger and more beautiful than garden or wood goldfinches, which again differ slightly from each other; the southern birds are more intensively coloured and lighter on the underside than the northern ones (Brehm quotes them as another species); the eastern, namely those from the Volga area, are specially large, and are often classed as a special sub-species. In addition to those quoted a whole series of analogous deviations are known—they are all characterized by the fact that they gradually pass one into the other.

Only in cases where species inhabit places separated from each other by insurmountable barriers do we fail to find forms transitional between the different local forms. Gulick describes such a case for the species of snail called *Achatinella*. This exists in the Sandwich Isles in many forms. In some areas these change by insensible gradations into one another; in others, where intervening areas are separated by mountains, &c., the species are very sharply differentiated.

Physiological variations include adaptation to a particular food, to a particular mode of respiration, to a particular temperature, to a particular method of moving, to living in a particular environment, &c. The phenomena of training may be included among the psychological effects of the environment on the organism. Other scientists classify these facts according to the nature of the stimulus—into reactions to light, to gravity, to temperature, to a dry atmosphere, to chemical influences, to climate, &c.

The so-called 'seasonal dimorphism' is a special case of the reaction of the organism to its environment. Wallace gave this name to the phenomenon noticed in those butterflies which live through two generations each year, one in the spring and one towards the end of the summer. The spring form differs from the summer form in the marking of the wings to such a degree that, before their connexion was recognized, they were placed in different species. This is indicated by the double names they bear to-day: *Vanessa levana-prorsa*, *Antocharis belia-ausonia*, *Lycaena polysperchon-amyntas*, and others. Seasonal dimorphism had already been recognized at the beginning of the nineteenth century. In 1879 G. Dorfmeister proved experimentally that it is the difference between the spring and summer temperatures, which causes the difference in the markings of the butterflies; for, by artificially cooling the chrysalis, he succeeded in obtaining the spring form from the summer one. The centrifugalizing of the chrysalis, or changing the atmosphere which it breathes, or lighting it with yellow light, brought about changes similar to those caused by a change of temperature. Recently many analogous cases have been cited. For example, if it develops in warmth and darkness the female chrysalis of the lemon moth (*Gonopteryx rhamni* L.) gives rise to butterflies coloured like the male, while ordinarily the female butterfly is much lighter than the male. In the moth *Doritis Apollo* a similar experiment gave the opposite result, for, influenced by cold, the males took on the colour of the females. Seasonal dimorphism also occurs among

the Protozoa, Rotatoria, and Cladocera; and, according to Von Wettstein (1900), it is seen too in certain flowers which bloom twice a year, e.g. in *Alectorolophus*, *Gentiana*, and *Euphrasia*.

All these researches into the influence of the environment on the organism have made it apparent that it is impossible to deduce the true Nature of the organism in this way. We begin to see that no variations due to the influence of the outside world lead to a change into a new organism; the organism stands revealed as something invariable, something whose fundamental nature cannot be altered; the changes of form, and other similar changes, only show how it behaves under many and varying conditions. The recognition of this fact has led some biologists to believe that variations in the organism brought about by its environment are merely direct adaptations. They point, for example, to the phenomenon of immunity; the organism can to some degree counteract the effect of certain poisons by the production of anti-toxins. It has also the power to adapt itself to certain conditions of light and temperature, by characteristic regulations of its vital processes. Many modern researches bear upon this problem, and it is therefore not surprising that our ideas upon the subject are still far from clear.[1]

[1] H. Driesch discusses this question very fully in *Die organischen Regulationen*, Leipzig, 1901.

XXIX

REPRODUCTION

§ 1. *Modes of Reproduction.*

ONE of the most important and characteristic features which differentiates the living from the non-living, is the power of reproduction. No organism is formed by the action of material forces, but each one is produced by a living predecessor. From the time of Aristotle, however, there have always been some who have maintained this assumption to be incorrect, and that there are certain circumstances under which spontaneous generation may take place. Moreover, the method by which life arises from life, a phenomenon without analogy in inorganic nature, presents a problem which is just as obscure in the lowest types of life as in mankind.

Life renews itself in two ways: the first sexually, when two individuals are essential for the production of the offspring; the second asexually, when one individual alone can produce another.

In asexual reproduction a smaller or larger portion of the body separates itself from the mother organism, and by growth and differentiation develops into a new individual. This individual exists side by side with the mother organism, which, in the meantime, has replaced the part cut off. If the organism divides into two roughly equal halves we speak of 'fission'; 'budding' takes place, on the other hand, when the newly developed organism separates from the body of the old one as a comparatively small branch. Finally, if it is produced from a single cell, which is usually formed in a special organ of the mother body set apart for its production, we speak of reproduction by 'spores'.

In sexual reproduction there are always two, if not independent individuals, then at least physiologically (sexually) different organs, whose products unite: the male, which forms spermatozoa, and the female, in which the

ova are formed. In exceptional cases one of the sexes (the male) can be suppressed. We then speak of parthenogenesis, when unfertilized females lay eggs capable of development. Among the higher animals, especially among mammals, parthenogenesis does not occur, although the eggs of birds and mammals often begin to segment without being fertilized. At a time when Darwin was still considering his theory, Hofmeister discovered that even the so-called sexless Cryptogams reproduce themselves sexually, but that here the sexual and asexual methods of reproduction alternate in a peculiar way. The green mosses form eggs and sperms, but the fertilized egg does not develop into another moss plant. It forms a capsule on a brown stalk, in which asexual spores are formed. These fall to the ground and eventually germinate to form a new sexual plant. Thus the little moss plant has two life periods: in the first it lives as a green plant, which forms sexual organs; in the second as a brown capsule, which forms asexual spores.

The ferns, horsetails, and lycopods all go through these two phases, though in them the sexual individuals are small and inconspicuous, while the asexual, on the other hand, are large, being (in the case of ferns) the actual fern plants, which bear asexual spores. Among flowering plants, the first, or sexual phase, is very much reduced. While the algae reproduce themselves now sexually, now asexually, the higher plants, from the mosses upwards, follow an ordered alternation of the two methods of reproduction; the higher the plant, the more developed is its asexual phase, and the more reduced the sexual phase becomes. The meaning of this alternation is by no means clear.

More recently the analysis of the behaviour of the chromosomes during fertilization has shown that there are specific sex-determining chromosomes; further, that the inheritance of sex follows the same Mendelian rules as does the inheritance of any other bodily character. This does nothing, however, to help in the understanding of the whole phenomenon of sex.

§ 2. *Theories about the Nature of Sex.*

The philosophy of sex, to which man has always devoted much thought, has passed to-day into the chromosome theory. Much of Aristotle's philosophical system originated in the recognition of the difference between the two sexes; this gave him his ideas about matter and form. In the female are embodied the passive principles, in the male the active, creative, formative principles. Even Harvey allowed himself to be influenced by these ideas, and he compared the female uterus with the brain; as the latter possesses the power to form images of external objects, so the uterus—whose ideas are the eggs—forms them in the image of the fertilizing male. In the speculations of the evolutionists of the eighteenth century the broader aspects of sex were absolutely neglected. The result of the discovery of eggs and spermatozoa was that the true nature of the problem was obscured. They imagined that they could answer all questions on the subject by examining those structures. The theory that the complete man lies already enclosed within the ovum or the spermatozoon suggested that one sex, either the male or the female, represented a superfluous, purposeless creation of mother nature!

The German romantic philosophers looked with wonder upon the phenomena of sex. Their most fundamental idea, that of polarity, was often inseparable from the idea of the contrast between the sexes. Even Schopenhauer devoted a special chapter to observations on the metaphysics of sexual love. Led by the poets, and by Goethe—the man of the world,—these philosophers were able to appreciate the fateful power of the differences between the sexes. Since Darwin's time, however, biologists have not considered the subject of any paramount importance. It is true that Darwin based his theory of sexual selection on the differences between the male and female of the same species. This theory, however, lacks most of the beauty which characterizes living nature. He only saw

in these differences secondary adaptations to the external conditions of life. Since then this subject has lost much of its significance. Blind to the processes of actual life, and carried away by their observations of microscopic structure, biologists have tended to look upon the problem of sex, under which, according to some philosophers, all the problems of the world lie hidden, as merely a problem of chemistry and of cell structure. From the fact that the spermatozoon and the ovum are both cells, it was inferred that there is no essential difference between them. By considering the sexual cells from which they originate, instead of the adult individuals, in all the fullness of their life and struggle, they concluded that there is no essential difference between man and woman; the differences which actually exist between them are, according to these theorists, merely special adaptations for the purpose of facilitating the union of the spermatozoon with the ovum.

'All the contrivances connected with sex are variations upon one and the same theme; firstly, they enable the sex cells to come together, and secondly, they insure that the egg shall be nourished and kept in safety. We call the one set of contrivances "male", the other "female". All these relationships are of a secondary nature, and have nothing to do with the real essence of fertilization; this is the union of two cells, and is therefore purely a cell phenomenon. In these views we agree with Weismann, Rich, Hertwig, Strasburger, and Mallpas, who have expressed similar opinions' (O. Hertwig, *Allgemeine Biologie*, 1902).

On this view one question alone remains: what is the meaning of the process of fertilization itself? In the simplest forms of life, as, for instance, the bacteria, there were originally no sexual differences. These developed gradually, and began in the fusion of two otherwise similar cells. To facilitate conjugation one cell gradually assumed a passive role, and the task of accumulating food; the other became more active, hence smaller, and sought out the former. Thus began the differentiation between ovum and spermatozoon. When, later, multicellular organisms developed, the process of reproduction was taken over by a

few cells, and for the purpose of facilitating conjugation the two sexes became differentiated in various directions.

This is the way in which Strasburger, Maupas, and Weismann accounted for the development of sexual differences. The latter also thought that these differences in sex play an important part in bringing about variation. The offspring inherits some characteristics from its father, others from its mother, and hence embodies a new combination of characters. Others have given such obvious explanations of all the facts connected with sexual life that there seems to be nothing which is beyond the comprehension of these scientists! Do we ask what is the basis of sex-love? Jaeger puts forward the hypothesis that it consists in a similarity between the exhalations of the male and the female, and in a chemical attraction set up by these exhalations. Pfeffer has actually succeeded in obtaining a proof of this hypothesis in the case of certain plants. Mantegazza also gave a very similar explanation. Others, like Nägeli, have considered that the attraction is electrical in nature.

But why do two cells strive to unite? why the electricity and the chemical attraction? The reason is not a very abstruse one! According to some scientists cell conjugation developed from a kind of cannibalism. One cell devoured its neighbour, became strong, passed on the capacity for devouring its neighbour to its successors, and so conjugation began. Jacques Loeb suggests (1906) that fertilization has the following significance: the spermatozoon brings into the ovum certain chemical substances which hasten segmentation; this can, however, be brought about without the help of the spermatozoon, merely by the influence of certain chemicals. A little potassium chloride or cooking salt is a substitute for the male element, as has been shown at any rate in Echinidae worms, starfish, and other animals. A mechanical stimulus (as has been demonstrated on the frog) may act in the same way.

Boveri (1902), on his side, compared the egg to a watch which has not been wound up; fertilization simply winds the spring, and this makes segmentation possible. Accord-

ing to him the essential factor is the centrosome, which enters the ovum with the spermatozoon. For Herbert Spencer also the object of fertilization was no mystery; life is like a constantly moving wave; the beginning of life resembles the heaving surface of the water; it becomes calmer and calmer as development proceeds; in the ovum such a great peace prevails that a new impulse must come to it from outside; the fertilizing spermatozoon is like a stone thrown into a pond; life is set in motion again, and the power for a new period of development is given.[1]

When we contemplate the activities and struggles of the Universe, it would seem as if the antithesis between male and female plays the most important part in the whole drama. The most beautiful and the most vile in practical life, in philosophy, and in literature, is developed under the spell of this antithesis. It is the inevitable inspiration of the poet. In every religion we find in its metaphysical foundations some solution of the question of the relation between man and woman.

But the men of science can only tell us of centrosomes and chromosomes; their exalted wisdom has revealed nothing more. *Tant pis pour elle*!

[1] A systematic account of the problems of sex is given by P. Geddes and J. Thomson in *The Evolution of Sex*, 1899; L. Dante, *La Sexualité*, 1899. H. His gives the history of the subject in 'Die Theorien der geschlechtlichen Zeugung', *Archiv. für Anthropologie*, iv, 1870 and 1872 (incomplete).

XXX

HYBRIDIZATION

§ 1. *Properties of the Living Organism.*

IDEALISTIC morphologists stopped short, in their analysis of animal and plant bodies, at the idea of organs; they did not consider the morphological aspects of this idea in any detail, for they saw in the organ only an instrument for life's physiological activities. True, there were some attempts at a more abstract analysis. The ideas of homology and of analogy, of segmentation, the vertebral theory of the skull, the theories about metamorphosis, the division of the plant into root, stem, leaf, and trichome, and indeed the whole distinction between morphological and physiological processes—all these represent endeavours to combat the opinion that the organism is nothing but a set of instruments for the performing of certain living processes. Yet no morphologist succeeded definitely and of set purpose in freeing himself from the domination of physiology. Lastly, excessive stressing of the general aspects of all these questions killed every attempt at any more detailed analysis of organic form.

Darwinism, as expounded by Haeckel, was made to include the whole of idealistic morphology, but it gave to this a very one-sided physiological bias. According to Darwin bodily structure is determined by the practical necessities of life. The discovery of the cell, an element which cannot be deduced either from the facts of general anatomy or of physiology, marks the first onslaught upon organography. The work on the cotyledon, the new theories of heredity and of variability, all helped to rob the morphology, which was merely organography, of its original importance, and to force it into the background.

The discussion of heredity and of variability led to a new conception, namely, to the idea of characters which are material, and in a sense unchanging, entities. The first

advance in this direction is seen in Darwin's theory of pangenesis. When he published it, it was not clear to any one that he was attacking organic morphology—that morphology which, rejuvenated and equipped with a new evolutionary terminology, his friend Haeckel had just sent out into the world anew. People welcomed Haeckel's work, but Darwin's theory of little invisible bodies suspended in the blood, which streamed through the entire body in order to settle in the sex-cells, was found very far-fetched. In spite of these facts, however, Darwin's theory exerted the more lasting influence. Great thinkers like Nägeli, Galton, and Weismann believed in the invisible bodies, and sought to explain how, with the aid of these bodies, the characteristics of the parents were transmitted to the children. Of what do these characteristics consist? Darwin did not puzzle over this question; he regarded as characteristics of the organism such diverse factors as, for instance, the length of its foot, the number of its teeth, the position of a blood-vessel or a single muscle, its intellectual capacity, courage, skin colour, and the ability to speak! Carried away by the materialistic tendencies of his time he could not help thinking of each of these characteristics as a little body, or group of little bodies.

It was not noticed that Darwin's resolution of the organism into characters represented a different conception of life from that which thought of organs, tissues, and cells. Haeckel simply ignored Darwin's discussion, as if it had never been. Weismann, a more acute scientist, took it up and distinguished between two different kinds of character—the inborn and the acquired. But, although much ink was spilt in the dispute about the inheritance of these characters, no one attempted to solve the problem: What is a character? It is true that Weismann dared to try to find out how many inherited characters one organism (Daphnia) possessed; he always believed, however, that the number could be deduced *a priori*.

Meantime other scientists were seeking to obtain a more accurate conception of these characters. Cope taught that

the same character can occur in different varieties and species. A mixing of the characters through crossing was also spoken of, but, in the current theories of the day, it was still assumed that organs and their parts represent the only conceivable elements into which an organism can be resolved. This idea was only gradually shaken off by thinkers who have striven to get a clearer conception of 'characters'.

The analysis of the organism into its characters has become a uniform, systematic study with a set programme. Since Mendel the outlines of such a study have come into view in the modern speculations on heredity, in the researches into hybridization, in the theories relating to the sudden formation of new forms, in De Vries' theory of mutation and in Johannsen's teaching about genes. De Vries, on his part, endeavoured to reconcile the cell theory with the theory of separate hereditary characters. He, too, believed in small hypothetical bodies which have these characters shut up within them; but even in his early work he laid more emphasis on the characters than on the material bodies which contained them. He proceeded to show that the same attribute, e.g. Chlorophyll, is present in one plant and absent in a nearly related plant, and is, therefore, not necessarily linked up with other attributes. The same shape of leaf, the same alkaloid, can be characteristic of different species of plants. Hence he inferred that every species consists of an aggregate of many characters, and that these can be repeated in different combinations in the various species. The task of the biologist, then, is to discover these characters.

'It is clear, therefore, that the characteristic structure of each species is the result of a combination of inherited characters, and that most of these are repeated in numberless other varieties. According to this view every species is an extremely complicated structure, and the whole organic world is the product of an infinite variety of combinations and permutations of a relatively small number of characters' (E. Baur, *Einführung in d. experimentelle Vererbungslehre*, 1919).

Recently this idea of characters has been further defined. By a character we do not necessarily mean anything material or structural, nothing, in short, actually existing; not an organ, or a colour, or the like, but such a feature as the specific and characteristic mode of reacting to a stimulus, the development, for example, of a definite colour in the flower.

§ 2. *Facts relating to Hybridization.*

The theory of unit characters has been advanced by the study of the phenomena of hybridization, even more than by the mutation theory. Among all living things it is the almost universal rule that for the production of a new organism two individuals are indispensable. In forms which possess the organs of both sexes, two of those hermaphrodites will usually unite for fertilization, even though self-fertilization is possible, and can take place when necessary. This fact was first observed in the eighteenth century by the German botanist Sprengel working on plants. He taught that nature, in various ways, hinders the direct fertilization of the pistil by pollen from the same flower, while it aids cross-fertilization by pollen borne on another flower.

Darwin accepted this hypothesis. It agreed with his observations on the relation between flowers and insects. Many experiments led him to assert that

> 'no organic being fertilizes itself for a perpetuity of generations; but that a cross with another individual is occasionally—perhaps at long intervals of time—indispensable' (*Origin of Species*).

It seems as if a very great similarity, or very near relationship between the sexes, hinders effective fertilization, and that a certain degree of dissimilarity is necessary to render possible a revitalization by the male or the female. But, if this dissimilarity passes a certain optimum, fertilization becomes more difficult again, or even impossible. And yet very dissimilar animals and plants can often be crossed successfully. The general rule is that two crossed varieties will produce offspring, but that a cross

between two species, on the other hand, remains unfruitful; there are, however, numerous exceptions to this rule.

Darwin paid a great deal of attention to the subject of hybridization. He thought the organism consisted of the sum of its characteristics, just as a number is from one point of view the sum of other numbers which lose their identity and become completely merged in the total. Darwin imagined that, in a hybrid between two forms, the characters are merged in this mathematical way; so that, in the hybrid, it is not the characters of the parents which appear, but the resultant of the fusion of those characters. In addition to this he tried at great length to prove that hybrids between species only differ in degree from those between varieties or between individuals, and that the sterility of the hybrid must be explained as due to secondary causes.

Darwin's relative, Francis Galton, accepted these views in every detail and enlarged upon them. Galton took it for granted that all characters merely represent quantitative deviations from some mean value, and that, in any cross, these will be combined in the descendant according to the mathematical theory of probability. Calculations into which we need not enter led him to the conclusion that the descendant always inherits a quarter of his characteristics from each parent, one-sixteenth from each grandparent, one-sixty-fourth from each great-grandparent, and so on. The same rule must apply in the crossing of forms which are not very closely related; if a cross once takes place the blood of both parents becomes so intimately mixed in the offspring that it soon becomes quite impossible to tell, from examination of the descendants, what the original ancestral forms were like. Nature was searched for hybrids which, having arisen in this manner, had propagated themselves as apparently new forms; many were found among plants (*Verbascum*, *Salix*, *Hieracium*, *Rosa*, &c.).

Meantime, another conception of hybridization was arising, though this was not yet referred to in the con-

temporary literature. The subject was being very actively studied during the first half of the nineteenth century. In England the significance of the experiments of Knight and Herbert was being actively discussed. In Holland Gärtner had put forward a whole series of new experiments and new theories; in France Naudin was studying the phenomena of hybridization. The objects of these experiments were very varied. In some the aim was to discover whether hybrids between two varieties follow different laws from those governing the hybrids between species. In others the aim was to see if we can produce new species by hybridization. In still others, to determine whether the hybrid is more like the father or the mother, and so on. There was a strong inclination to regard hybrids as unnatural products, which do not pass on the characters inherited from both parents, but whose descendants tend to revert to one of the parental types.

Darwin discarded these ideas, and diverted the whole investigation into other channels. There were, however, certain scientists who did not follow Darwin's lead. Naudin in France and Mendel in Mähren followed the old line of investigation, and paid no attention to the change in public opinion. Naudin believed that hybrids must be looked upon as unnatural forms, in which the characters of the parents do not unite, but remain lying side by side, only to fall asunder when further breeding takes place. The professor of the Brünn Gymnasium, an Augustine priest, also held to the old views, but he gave to them a deeper significance. He imagined (*a*) that the organism is made up of a number of characters, somewhat as substances are composed of atoms; (*b*) that in hybrids between related forms the characters of the parents do not fuse, but lie side by side; (*c*) that of these characters as a rule only one develops while the other is latent. Into each sex cell (ovum and pollen grain) of the descendants only one of every such pair of characters enters; so the characters of the grandparents form new combinations in these cells; in every egg, in

every pollen grain, there is a group of paternal and a group of maternal characters. The number of possible combinations of these characters will follow the mathematical laws of probability.

If the hybrid propagates itself further by self-fertilization every pollen grain unites with an egg; if these happen to contain the same group of characters a descendant ('a mongrel') is produced which has some of the characters of the grandfather and some of the grandmother; but it possesses each such character in its pure form; such a form is a constant one. If, however, the characters in the egg and in the fertilizing pollen grain are different, a form (hybrid) arises, in which double characters appear again. These can then only be separated by further self-fertilization. By continued self-fertilization among the hybrids we can calculate mathematically how many different crosses will be produced in each generation. If n is the number of characters in which the two parents chosen for hybridization differ, then 3^n is the number of all the possible different kinds of crosses which will be produced. From the hybridization of two varieties of peas which differ from each other in three characteristics we get in the second generation 3^3, or 27 different forms, of which 2^3 or 8 will be constant forms. The difference between this conception of characters and that of the orthodox Darwinists is seen very clearly in the difference between Galton's and Mendel's theories of heredity. According to Galton, who in this respect was only expressing the views of his time, the characteristics of the parents have a resultant effect on the descendant, like that of two forces working simultaneously on one body. The result is uniform, and nobody could resolve it into its components unless he knew the nature of those components from some other source.

Following out this idea further, Galton believed that every individual is influenced, in a greater or less degree, by all his ancestors, so that no ancestor can reappear pure in any descendant. According to Mendel, however, the

characters of the parents are combined in the descendants, but do not fuse, so that they exist there side by side, and can separate again in future generations. No fusion of characters takes place, and hence the ancestor can reappear unadulterated in one of his descendants.

The theories of Naudin and of Mendel aroused no interest, though the latter based his on accurate experiments. They appeared when the teaching of Darwin was at its very zenith, and the Darwinian theory did not touch upon this idea of the resolution of a plant into unit characters. True, Mendel did draw the attention of Nägeli to his experiments, but even the latter could not gather anything from them which seemed to him important. There are yet further reasons for this neglect. Mendel's experiments were carried out without a microscope and with cultivated plants; this in itself stamped him as mediocre and amateurish. He published his discoveries in a little known journal. Further, the fact that he was a monk was not without significance. How could such a one contribute anything in support of the prevailing Darwinian teaching? His work was only rediscovered in recent years, long after his death. Mendel's theory, which was based on experiments upon one species of plant, forms to-day the basis of the modern science of heredity. New ideas were built up on his theory as a foundation. A large number of facts, botanical and zoological, from medical science, and even from psychiatry, have been collected which seem to support it. In this work of collation limits beyond which the theory does not seem to hold have often been encountered. All this work has, however, begun seriously to undermine the foundations of Darwinism.

XXXI

THE MECHANISTIC VIEW OF DEVELOPMENT

§ 1. *Some Theories.*

IDEALISTIC morphology was flourishing at the beginning of the nineteenth century. Its methods were comparative, its subject-matter the bodies of mature animals and plants, its goal the understanding of the nature of these forms. A few isolated scientists tried to break through the boundaries within which this subject was confined; they retained the old methods, but they extended the subject-matter, taking abnormal forms into consideration. Many leaders of thought in the realm of morphological science—among them Geoffroy St. Hilaire, Meckel, and De Candolle—furthered this endeavour. Geoffroy turned to the study of human monstrosities in an effort to find further evidence in favour of his principle of unity in organic design. Meckel, with true German industry, collected all the known facts about pathological structures in man, and produced a work which, in relation to the knowledge of that period, is as important as was Darwin's later work dealing with an analogous subject—his *Monograph on the Variations of Animals and Plants under Domestication*. De Candolle, from the study of vegetable monstrosities, came to very definite conclusions about the normal structure of plants.

When morphology began to claim less attention the work of Schleiden and von Baer became increasingly important; mechanistic and causal explanations of form began to be discussed. Just at that moment (1852) *An Anatomical and Physiological Survey of the Animal World* was produced by two German zoologists, C. Bergmann and R. Leuckart. These authors set out to include the physiology of structure in all discussions. The following words indicate their programme:

'If we have been successful in unravelling any thread, from the

tangled skein of causative factors which lies behind the evolution of animal form, then morphology will henceforth become a part of physiology. Just as, to-day, we strive to discover the complex interplay of forces which leads to certain forms of crystal, or to the formation and differentiation of the cell, so, in the future, we shall endeavour to invent new lines of work, which will enable us to investigate those causes which influence the arrangement of organs; hence, at some future time, we shall be able to work towards a physiology of plastic form.'

As can be seen, the two authors did not attempt to realize their programme; they were content to suggest that there is a connexion between the structure and the function of an organ, and they left to the future the task of explaining the organ by elucidating its cause.

This suggestion of Bergmann and Leuckart was simply overwhelmed and lost sight of in the flood of Darwinism; morphology was supplemented, not by the study of physiology, but by the study of ontogeny. Under the leadership of Gegenbaur and Haeckel it was gradually changed to a discussion of genealogical descent. The next task was to describe the embryonic development of each form; and because each organism begins as an egg, which segments into two cells, into four, and so on, until finally tissues and organs are formed, attempts were now made to determine from which cell each part of the body arises. The comparative method, it is true, had been renounced. Nevertheless this new science was called comparative, to distinguish it from human anatomy and embryology on the one hand, and from systematic biology on the other. Henceforward, however, scientists were not endeavouring to formulate general ideas on the basis of comparison. They were searching in their comparisons for the causes of structural change. The fundamental law of biogenesis had gained such universal acceptance that no one thought of looking for these causes elsewhere than in antecedent structural conditions. As the historical fact that candles were used in the catacombs is the reason why they are burnt on altars to-day, so the cause of the gill-clefts in

mammalian embryos was supposed to be the fact that the ancestors of the mammals had once been fishes. The hypothesis that all multicellular organisms have been evolved from an amoeba was believed to explain why every animal begins its developments from an egg-cell.

Haeckel had no hesitation in calling such causes 'mechanistic'; still less so as he believed that the only possible opposition to his theory was that opposition which was inspired by theology. His views were eagerly accepted by all orthodox embryologists, and, during the 'eighties, embryological science was studied most enthusiastically. Haeckel's pupils hold fast to his teaching even to-day. One of them, O. Hertwig, says:

'Is not the fact that the eggs and sperms are elementary organisms or cells in itself causal?'

Hertwig, it is true, is looking for the forerunners which determine the various stages in ontogeny in those forms which preceded the present ones only by hours or minutes, rather than in those which preceded them by millions of years. In principle, however, he is of the same opinion as Haeckel. The egg is the *cause* of segmentation. This, in turn, leads to the embryo. The embryo is the *cause* of the mature form, even as to-day is the *cause* of to-morrow. He hopes by giving a very minute description of the successive stages in development to attain to a very exact knowledge of causes—a knowledge of almost astronomical precision and exactitude.

Haeckel's elucidation of causes did not give any general satisfaction, however. It clings too closely to the mere details of practical experience, and denies all rights to that more soaring intelligence which strives to realize what is persistent in a world where all is changing, and what are the universal laws which underlie all such change. He scornfully challenges every attempt to understand ontogeny when he says

'each of these simple ontogenetic processes of unfolding is the result of an extremely complicated series of historical events. It is causally

determined by the thousands of phylogenetic changes, by the innumerable hereditary and adaptive alterations, which the ancestors of the organism in question have undergone during the course of millions of years' (E. Haeckel, *Ziele und Wege der heutigen Entwicklungsgeschichte*, 1875).

Does not this suggest that the organism of to-day merely represents an accumulation of chance occurrences, with which intelligence has had nothing to do?

Intellect, however, could not be thus thrust aside for very long. Attempts were soon in evidence, not only to describe, but also to understand, development. The Leipzig embryologist His, an opponent of Haeckel, tried to explain embryology in accordance with the views of Bergmann and Leuckart. He declared that Haeckel's phylogenetic methods tend to make us avoid a direct explanation, and that we must try to understand *why* each succeeding embryonic stage is the necessary sequel of the one which precedes it. His believed that the mechanical causes of the phenomena of development will be found if we examine the processes of growth. The embryo of a mammal is at first like an elastic plate; it grows unequally, and hence crumples like a piece of damp paper. These first folds mark the limits of the various parts of the body, and these parts form themselves subsequently by further foldings. When we have found the law which governs the growth of the various parts of the embryo we shall be able, aided by this mechanical theory of folding, to understand the whole development. It will not then be necessary to explain the different embryonic stages historically.

His endeavoured to obtain experimental proof of his theory of foldings, but his experiments consisted merely of very rough analogies; he examined the mechanical bending of wooden plates, and drew attention to the crumpling of layers of rock—phenomena so far removed from those of development that it is not surprising that his theory found few ready to accept it. This was the case, even though several scientists, among them Kölliker,

had given their support to the thesis that development must be explained directly.

The zoologist Goette, who was also incited to this work by Haeckel's theory, spoke in favour of a direct explanation of embryonic development (1875). In contrast with His, however, he suggested a theory which was vitalistic in its tendency. The 'principle of form' must govern development, he said. He expressed his thoughts in such an obscure style, however, that his theory attracted even less attention than did that of His.

In 1880 the anatomist Rauber made another attempt, in a paper on *The Creation and Destruction of Form*, to replace Haeckel's theory by some more exact hypothesis. In this work, pursuing the line of thought suggested by Bischoff the embryologist (under whom he had studied), he examined and discussed the monstrosities which often occur among healthy fish embryos. Bischoff was an idealistic morphologist, and was directly under the influence of Geoffroy and Meckel. All that Rauber did was to develop these theories further, but, being a disciple of the new mechanistic conception of life, he referred to Lotze and not to Bischoff when discussing the philosophical foundation of his theory. He considered that Lotze was a philosopher who was underrated by the Germans, and that his work was very important for embryologists; for this antagonist of the theory of vital force had used facts obtained from ontogeny to prove that a strictly mechanistic view is an intellectual necessity; development is merely irregular growth, he had asserted—growth which results in a number of secondary changes of position

'which partly *appear* to be the result of displacements, protrusions, invaginations or extensions, and in part *are* really produced in one of these ways, being then the result of mechanical tensions and pressures.'

Lotze had also compared the processes of folding off of the embryo from the ovum with analogous processes in the earth's crust, as His did later. Lotze, then, according

to Rauber, must be referred to in any attempt to enlarge upon and perfect Haeckel's views. We must seek 'a knowledge of the forces, or the systems of forces, which enable the germ to embody all the forms mentioned; to pass from the first form, through all the transitional stages, until it reaches its final phase' (A. Rauber, *Formbildung und Formstörung*, &c.).

A new science, a 'cell-mechanics', must be founded and ontogeny merged in developmental mechanics. The elements of this mechanics, according to Rauber, are cell-divisions, cell-growth, cell-migration, and differentiation.

In a later treatise Rauber modified these ideas in one respect. He no longer believed that cells are the factors which chiefly determine the course of development. He believed that the form of the mature individual is the guiding principle which directs this development.

These writings of His, Rauber, and Goette were not important because of any new concrete discoveries which they proclaimed. What characterized them was the scheme for a new science which they promulgated. But who was to follow the suggested programme if not the authors themselves? The rest of the scientific world had its own programme, which Haeckel had forced upon it; this programme had first to be depreciated in the eyes of the scientist before he would be ready to consider the introduction of a new one into his laboratories. Not every scientist, however, was ready to welcome such a change. Roux was the first to be successful in the task of gaining a hearing for the new ideas.

§ 2. *Roux's Evolutionary Mechanics.*

In the early 'eighties Wilhelm Roux, then Professor at Halle, suggested that there may be an internal struggle for existence between the various elements of the individual body. This suggestion helped to broaden the prevailing ideas about Natural Selection.

Soon after this Roux endeavoured to see where Haeckel's

embryological views would really lead us, if followed to their logical conclusion. His very early work, done in 1879, already gave evidence of the line of thought which he was destined to follow later. This early work was an investigation into the causes of the branching of blood-vessels. In 1885 be began some experiments on the development of a tadpole from an egg which had been damaged, and in this work his point of view was expressed even more clearly. In 1894 a new journal began to appear —*The Archives for Developmental Mechanics* ('Archiv für Entwicklungsmechanik')—in which the results of this new branch of science could be made public.

Roux is Haeckel's pupil. His problems are the same problems, his line of thought is that of the keen protagonist of Monism. Development—the development of the bodily machine—is the subject-matter of all their work. Their object is to ascertain the causes of this development. Roux believes in a mechanistic world, even as Haeckel does. But what were principles and postulates to the master-mind of Haeckel,—principles and postulates which were enunciated with great decision, it is true,—were treated as if they were concrete facts by his pupil.

Haeckel's theories dealt with the subject-matter of idealistic morphology, but his aim was always to deduce causal and mechanistic explanations of the facts. His facts were the facts of systematic zoology; his desire was to confirm his theories by a study of development. In practice he began with the study of form, but in his theories he stressed function as the primary phenomenon.

Roux had not imbibed the ideas of idealistic morphology in his youth; he did not hesitate to fit his facts into Haeckel's philosophical scheme, and the result was that he presented, in what he believed to be a concrete form, the ideals which had been preached by Haeckel. In place of the much more difficult phylogenetic development, Roux examined the ontogenetic development, and relegated the historical facts to a place of secondary importance. He, too, endeavoured to discover the causes of form, but he

claimed to have perfected Haeckel's method; for he did not rely upon comparisons only, but upon actual experiments. He was, like his teacher, a believer in the mechanistic theory, but he did not believe in 'far-fetched speculations on atomic oscillations' or in 'explaining' the soul through nervous activity, or the like: he tried to demonstrate his facts concretely, and to show that these mechanical forces reveal themselves as pressures, tensions, and flexures during the course of embryonic development.

This endeavour to put Haeckel's ideals into practice, however, caused Roux unwittingly to overstep the boundaries of orthodox Darwinism. Roux no longer believed that the task of the scientist is to give an intelligent picture of what is actually happening in nature. Science which merely gives a photographic picture of Nature did not satisfy him. In all his works there is an endeavour to understand Nature, to know how she works in her magnificent workshops. And so he did not think very highly of the so-called 'descriptive' embryology of the previous decade. There had been no attempt in that work to discover the causes of events. (The idealists of a still earlier age had, it will be remembered, raised the same objection to mere descriptive embryology.) Roux rejected it because the descriptive method can give us no certainty that its assertions are justified. Such certainty can only come from experiment.

Roux now began to assert the rights and claims of Reason—claims energetically denied by the evolutionists. This was not the old Reason of the idealists, which was seeking for 'logical causes', and for 'ideas' which revealed themselves in Nature. It was the reason of Darwin and of Mill, which strives to ascertain what are the actual objective causes of all events, those causes which precede the event, and are themselves preceded and caused by still earlier phenomena.

The difference between Roux's views and those of the orthodox evolutionists will be clearer if we contrast them with some of the objections and criticisms which emanated

from Hertwig. Hertwig was likewise a pupil of Haeckel, but he has a much less independent mind. He declares, first of all, that he cannot imagine how Roux can hope that this attempt to discover the causes which lie behind phenomena will lead to anything intrinsically new, for it has been for long the avowed goal of science to elucidate the main causes of events: 'The theory of development, as it has been presented to us, does not teach us bare, unconnected facts; it presents us rather with a series of facts, which stand in an absolutely essential and causal relationship to each other.' [1] Certainly they do, we answer to this assertion, which is so very characteristic of the old type of Darwinian argument; but of what use is it for us to know that they are causally connected, if we do not understand what were the causes? With unerring insight, Roux saw that those genetic ideas which affirm that the past is the cause of the present would, if true, provide us with a complete description of both external and internal development—a complete cinematographic film of development, in short. This ideal did not satisfy him, however. He wanted to know by what forces each little particle in the germ is driven on along its allotted road.

'We do not know what forces are present in the egg, what is their arrangement, nor how they are able to initiate the complicated series of changes which leads up to the development of a new individual; nor do we know what combination of forces influences the further progress of development. In short, we have no idea why a highly complicated organism, with the structure typical of its kind, is formed from the relatively simple egg; nor why an organism, once formed in this way, remains comparatively unaltered in spite of the fact that the matter of which it is composed is constantly being renewed' (W. Roux, *Programm und Forschungsmethoden der Entwicklungsmechanik*, 1897, p. 15).

[1] O. Hertwig, *Zeit- und Streitfragen der Biologie*, 1897. In the same book he makes a statement which is typical of Darwinistic mode of thought:

'For the words Reason (Grund) and Inference (Folgerung) we can equally well substitute the words Cause (Ursache) and Effect (Wirkung).' He who sees no difference between a reason and a cause will naturally find nothing new in Roux's work. At a later date Hertwig rejected Darwinism. See his *Zur Abwehr des ethischen, des sozialen, des politischen Darwinismus*, 1918. Einhorn gives an

Roux founded a new branch of science, which was to solve these problems and to ascertain the causes of organic form. Using the material already acquired by descriptive embryologists, we must, he affirmed, now search for the forces which preside over the formation of the organism from the egg. Such an experimental science will surpass descriptive embryology, as every science based on experiment surpasses one based on mere description. It will be a causal morphology, closely akin to physiology; but while the object of the latter is to ascertain the causes underlying the processes going on in the mature body, developmental mechanics will seek for the causes leading to the initial development of that body.

This endeavour to explain embryonic development causally and experimentally led Roux into further opposition to orthodox Darwinism. In theory Roux remained a mechanist. He could not, however, refrain from ascribing to the form of the organism a greater significance than it had previously enjoyed. His attempts to analyse form definitely suggest that changes in form are extremely significant. After he had studied the facts of regeneration, and certain cases where development had been artificially interfered with, he came to regard form as of even greater importance. Resulting from this Roux affirmed that chemistry and physics are of minor importance; the chemistry and physics of living substance are only distantly related to these problems of form.

This emphasis of the 'How' in processes of development very soon led the followers of the new movement to ignore the facts of normal development, although in the beginning they had aimed at explaining ordinary development. They soon came to regard all changes of form, whether normal or produced by artificial means, as of equal significance; the change in form itself became the subject-matter of developmental mechanics.

account of Hertwig's attitude to Darwinism in his book *Erfahrungs- und Deszendenzlehre. Eine Kritik der Grundlagen der modernen Entwicklungslehre im allgemeinen und des biolog. Grundgesetzes im besonderen*, 1924. The book contains a very good criticism of Darwinism.

Do the separate parts of the egg develop into the organs to which they give rise because of the action of innate forces (i.e. by self-differentiation)? Or does the mature organism represent the result of action and reaction between itself and its environment, i.e. is it the outcome of a differentiation dependent partly on external factors? Roux asked these questions, and regarded them as among the most important which developmental mechanics had to solve. Another equally important task for the scientist was to ascertain the place and time, where and when, each formative factor begins to influence the embryo. Roux sought to solve these problems by work on frogs' eggs. Earlier embryologists had observed that a definite relationship exists between the arrangement of the substances in the egg and the arrangement of the organs which develop from that egg. Weismann taught this in his theory of the germplasm, while His asserted that the future embryo is to a certain extent pre-formed. Roux now set to work to obtain experimental facts which would support this theory. He observed that the first segmentation, which divides the egg into two parts, generally coincides with the median plane of the future body; he killed one of the two cells resulting from this segmentation, and, from the surviving one a half embryo, either a right or a left half, developed. Roux believed that, in this manner, he had proved experimentally that, at the first segmentation, each daughter cell represents one half of the future body. He used this fact to support his 'mosaic theory' of the egg, according to which the organs are pre-formed in the egg as rudiments lying side by side.

These experiments were shown later to be inconclusive, and so the mosaic theory was not accepted. But they stirred other scientists to similar experiments, and the new subject gained many disciples. Many events contributed to this end. Roux was an eager advocate; he defended the new science against all attacks, and founded a journal for the debates and discussions connected with it. He endeavoured to set those who were engaged in building up

the new theories free from practical difficulties. If he had made this subject a branch of physiology, calling it 'the Physiology of Development', as some wished, he would have prevented his followers, most of whom were recruited from the anatomists, from filling the Chairs of Anatomy in the universities. So he called his new science 'Developmental Mechanics', and claimed that it was a more modern and more exact branch of anatomy.

Nevertheless, developmental mechanics did not gain a firm foothold in Germany. The influence of Darwinism was, and still is, very profound; Roux, however, found numerous and active adherents in America. Developmental mechanics was principally concerned with the phenomena of regeneration, with the influence of physical and chemical agents on the form of the organism (the effect of light, heat, gravitation, of oxygen, of distilled water, of various poisons, &c.), and, we may add in many cases, with the phenomena of fertilization. Later on, under the influence of Driesch, this branch of biology has been led into new paths. After the war the German embryologist, Spemann, attacked the problem anew. He and his pupils carried out many original experiments, by which they sought to revivify Roux's ideas, and to show that there are, in the embryo, specific centres from which the differentiation of organs is controlled.

The work described above altered the centre of gravity of all that research which had been inspired by Darwin and Haeckel. Phylogeny was relegated to a second place, if not quite discarded. Genetic ideas were still predominant, but these ideas assumed a more concrete form; they were gradually merged in a science which dealt with visible changes in structure.

XXXII

DRIESCH

§ 1. *The Nature of Development.*

WHAT Roux had done thus unwittingly and against his own intention, Hans Driesch carried out quite consciously and consistently. He renounced Darwinism. In his own special work he was Roux's pupil. He worked in the field of developmental mechanics, and at first he followed the methods and the ideas of his teacher. Later he became more independent, and to-day he is definitely opposed to his former teacher. Experimental researches into the problems of developmental mechanics formed the starting-point of all his work. He was interested above all in development. Explanation along genetic lines, the search for cause and effect, seemed to him the goal of all scientific endeavour.

The further Driesch went the more he freed himself from the bonds which bound him to the mechanistic views of the nineteenth century. He began by following those mechanistic views to their logical conclusion. Seeing that they are untenable, he became a convert to vitalism. As this failed to satisfy him, he then propounded his own vitalistic theory. In many respects Driesch differs from every other modern biologist. In all his writings, difficult as they are, we feel that he is endeavouring to avoid the garrulous superficiality which characterizes so many of them. He is trying to express the quintessence of being, to confine within the limits of speech the greatest and the most elusive truths. In the end he has come to agree with the views of that original interpreter and critic, Emanuel Kant.

Driesch marks the end of Darwinism. The world paid no heed to him, did not understand him, opposed him, sought for compromises, but Darwinism could not be saved. He raises the same objections to Darwinism as did

Roux and Goebel, but expresses them more pointedly. His main charge is that it gives no rational insight into events.

'Even supposing that the theories are correct, what can it matter to us that, at the present moment, such and such forms are existing on our earth, and that they have followed one another in such and such a sequence? This is a theory to which any inquirer into the more profound and more general aspects of Nature is absolutely indifferent—indifferent because historical ideas which are limited by time and space form no part of his inquiry' (*Die Biologie als selbständige Grundwissenschaft*, 1893).

He barely touches upon those questions so important to the Darwinists—questions about the origin of species and the development of the organic world, and he no longer asks whether Natural Selection is all-powerful or only partly efficacious. Driesch asks instead, whether life is really nothing but a special combination of chemical and physical processes, or whether it is not governed by its own peculiar laws. His opponents, the upholders of the opposite view, had scarcely had time to collect their arguments against this suggestion that the biological sciences are absolutely different from all other sciences, when he was attacking the question again. He now presented it as a choice between a belief in a living and directing force and a belief that life is purely mechanical.

The contrast between Roux and Haeckel became, in the hands of Driesch, a contrast between the first and second halves of the nineteenth century—we may even say, a contrast between the whole of modern science and the views of Aristotle.

We have already described the embryological work which endeavoured to determine how the various tissues of the body are formed from the egg; it assumed that, during segmentation, the characters of the future animal are separated, and enter the two daughter cells. As division proceeds, these characters become more and more separated, being apportioned to the various cells in an absolutely definite manner. His, Ray Lankester, Roux,

and Weismann upheld this theory, in its various modifications; it is based upon the assumption that the whole organism is already contained within the egg.

This assumption is contradicted, however, by the facts of regeneration, a phenomenon which is very intimately connected with the problem of the true nature of the organism. It becomes even more improbable in the light of Driesch's observations that from one isolated blastomere (in the case of the sea-urchins and other forms) a whole larva can develop; Roux's attempts to produce a half larva by killing one blastomere of a frog's egg were, it seems, very inexact. When the cells (and nuclei) of various stages in the segmenting sea-urchin are subjected to pressure, and so brought into thoroughly abnormal relative positions, this does not necessarily prevent the formation of a larva. Driesch pointed out later (and a number of scientists have confirmed this observation) that a whole larva can develop from fragments of an egg, if these are large enough and contain the nucleus. One or more cells can be isolated from the two-, four-, or eight-celled stage of the echinoderm embryo, and from each single cell, or each group of cells thus isolated, a whole larva can be produced; again, from two eggs which have fused into one, only one normal larva is produced.[1]

These observations led Driesch to formulate a new theory of development. Instead of the ordered pre-formation which other workers had postulated, he suggested that there is a continued setting free of new structures. He called this hypothesis a theory of epigenetic or emergent volution. He suggested that the chemical structure of the egg is comparatively simple. The influence of the environ-

[1] At first Driesch affirmed 'that any portion of the egg, as well as the whole egg in any position whatsoever, can produce a complete larva', that 'the egg cannot, structurally, be built up out of different elements arranged in a specified and typical way'. See *Die Lokalisation morphogenetischer Vorgänge*, 1899. Under criticism, he restricted this assertion, and admitted that there is a spatial structure which dominates development.

Many writers, particularly Jul. Schazel, have attacked Driesch's theories, from the mechanistic point of view.

ment causes chemical change, which changes lead on to others, and so the process continues. If this picture is true, development is merely the liberation of a series of chemical processes which follow one another. This liberation depends on the one side upon the chemico-physical structure of the egg, and on the other upon the influence of the environment.

These processes are absolutely different from inorganic processes, for they are in their essence teleological.

> 'The processes of ontogeny, both in their form and their sequence, take place as if they were guided by an intelligence.'[1]

The structure of the organism is characteristic of it, and it is causally inexplicable. It can only be judged teleologically.

Later on Driesch abandoned this view, which he calls 'static teleology', and adopted in its place the ideas he calls 'dynamic teleology'. He himself has told us that he developed these ideas after a consideration of 'counter-reactions'. An answer to a question, for example, is just such a counter-reaction; we cannot picture it as something merely mechanical—for it is not merely a reaction; it is ideally related to the question which is the cause. Organic reactions involve similar responses. If a triton loses one of its feet, it responds to this 'cause' by forming a new one. The newly grown limb is formed on the pattern of the one which has been lost, and is similar to it in both size and shape. We may affirm that we 'understand' this reaction, even as we affirm that we 'understand' the answer to a question. But the unit which determines and directs the reaction is the normal and complete animal; this is obvious from a study of the processes of regeneration.

Driesch endeavoured to explain every biological problem in this manner. He collected and sifted all material that could possibly be used to illustrate his theory of 'reactions of response', or 'regulations', as he afterwards called them (*Die organischen Regulationen*, 1901). He extended his theories

[1] H. Driesch, *Analytische Theorie der organischen Entwicklung*, 1894.

beyond the purely embryological processes, and made them include physiological and psychological phenomena, recording new experiments in their favour. We may quote a few examples of these processes of organic 'regulation'.

An organism may gradually accustom itself to certain poisons—it then possesses what is called 'acquired immunity'. If the poison is administered in ever-increasing doses the organism learns to produce certain anti-toxins which render the poison innocuous. This production of anti-toxins—which are not produced by the organism in normal circumstances—is a regulatory process by means of which life is maintained. A willow twig planted in the earth forms adventitious roots, and regulates its growth and form in such a way that a normal plant is produced. Crabs with stalked eyes will regenerate their eyes if these are removed; they form an antenna in place of an eye, however, if the eye ganglion which lies in the eye-stalk is removed as well. Here the crab reacts to the injury in two different ways; these can still be regarded as 'regulated' reactions.

Such observations led Driesch to formulate a dynamic interpretation of Weismann's theories. Weismann's idea was that the characteristics of the organism are pre-formed in the egg, existing there as tiny particles. Quite apart from the impossibility of picturing 'lung-breathing' or 'four-footedness', for instance, as embodied in little particles, this theory gives us no insight into the processes at work, no picture of the gradual development of those features which are characteristic of the organism. Driesch, too, imagines that these characteristics exist in the body, but as possibilities only, endowed with an impulse towards self-realization. The egg, and every embryonic cell, possesses a 'prospective power', i.e. a capacity to develop definite characters; the prospective power of the egg will lead to the development of the whole organism. A sufficiently large piece of an echinoderm egg, if it contains the nucleus; one of the two, or four, or eight blastomeres of the echinoderm embryo—all these have the same

prospective power. The ectoderm and endoderm of the echinoderm have different prospective powers, for, if isolated, they can only reproduce their own kind. The blastula cells of the echinoderm, on the other hand, are all of equal power. Delving deeper into these ideas of 'prospective power', and of 'organic regulation', Driesch was led on to the view that life is 'a law unto itself', that it stands alone and apart from the processes of the inorganic world.

After the decline of naturalism, the theory held was that there is no essential difference between the animate and the inanimate; that life is only a very complicated chemico-physical process—a machine-like process, where the word 'machine' is used in its most generalized sense, to imply a multiplicity of processes occurring in space and time. Driesch discarded this mechanistic theory of life, and opposed to it a 'dynamic-vitalism', a theory of the 'autonomy of living processes'. He gives four proofs, which are intended to demonstrate that this theory is the only possible one, and that the mechanistic theory is untenable.

His first argument is as follows: If development could only follow one fixed path, it would be possible to think of the egg as a highly complicated machine, which, by the interaction of its separate parts, is able to produce the complete organism. But any one cell of the two-, four-, or eight-celled blastula can give rise to a whole embryo. Similar cells may produce very dissimilar products; while, on the other hand, the same structures may be produced in various ways. Thus one cell of the four-celled blastula gives rise to quite different organs, according as one, two or three of the blastula cells are removed. These facts do not agree with our conception of a machine. Consequently there must be a factor at work in organic development which is neither physical nor chemical but vital.

Driesch derived his second argument from the facts of development, such as are furnished by a study of the blastula of the echinoderm. This is formed by the continued division of the egg. And yet each of its cells (or

groups of cells) can function instead of that egg. There is, however, no conceivable machine which can continually divide, and of which each part is equivalent to the original machine; therefore the egg is absolutely different in nature from a machine.

The third argument was based on an analysis of behaviour. In the actions of men and of animals experiences are combined to form ideas. This implies a process which is anything but mechanical. It is true that we can picture a machine which is able to collect experiences, as is a phonograph, but it lacks the power of combining those experiences, as a man combines the words he has learnt, in order to express new ideas.

The fourth argument against the theory of mechanical action is derived from the study of the physiology of the brain. If a portion of the brain is removed its functions are performed, after a time, by another part of the brain which had not hitherto undertaken that work. The basis of action is therefore not a hard and fast mechanical or constructional relationship existing in the nervous centres of the brain.[1]

§ 2. *The Theory of Entelechy.*

The idea of entelechy was formulated by Aristotle. He believed that this conception would enable him to harmonize the idealism of Plato and the facts of actual experience.

According to Plato we must distinguish between two distinct worlds. The world of eternal reality is known by the mind, but there is a world of continual change which we know through the senses. Snow, an animal, a rose, represent ideas which underlie the separate and transitory natural objects known to experience. These ideas exist in the mind, pre-formed, and we remember them when we consider the world around us. Aristotle accepted this theory of ideas, but not the theory of two worlds. He taught, for instance, that a definite plant, which I now have

[1] Driesch's Vitalism is expounded most simply in his *Der Vitalismus als Geschichte und als Lehre* ,1905.

before me, is only a transitory phenomenon, which does not represent any idea in the outer world, but forms merely a passing stage in the realization—the embodiment—of that plant. The analogy of the architect is the most appropriate one. He builds the house according to a plan; this plan is realized in the house. It is characteristic of the plan (which was conceived in the mind) that it is not made up of separate parts, that it occupies no space, that it cannot be perceived by the senses; that it is, in short, an idea which dominates the construction.

In order, however, properly to understand the Aristotelian conception of entelechy, we must not think of the idea as separated from the fabric. In considering living objects this error is a very natural one; when a plant is produced from the seed a highly complicated structure is realized. Here it is the idea of the plant which controls the structure, regulates the supply of power and of building material, repairs injuries, and gets rid of obstructions. This something which makes the life of every single organism a reality, Aristotle (and Driesch with him) calls entelechy. Entelechy is no mechanism, it is nothing spatial, for it is not in the seed; it cannot be asserted that one part of it is here and another there, but it is, like the plan conceived in the mind, everywhere at once. If a branch is broken off a plant, the entelechy remains whole, for the plant can reproduce that branch; if a new branch of the same kind is grafted on to a plant, its entelechy grows on as a uniform whole; if four cuttings of the plant are planted in the earth, we do not get four new entelechies but merely four repetitions of the same process.

Entelechy is, therefore, an agent with definite capacities. Its power is revealed in development, in the regulation and execution of physiological and mental processes. Its capacities are made manifest by the manner in which these are executed. It is comparable with physical and chemical constants. As the constants for iron show how this substance expands with heat, according to the general laws of expansion, how it conducts electricity, what is its

specific gravity, &c., so its entelechy is characteristic of the manner in which a definite organism acts. The inorganic constants likewise have no spatial significance; it would be quite useless to investigate how in any piece of iron the colour, gravity, specific heat, &c., are distributed, since they are present in every particle of the iron; they therefore do not represent any extensive, but rather an intensive reality, like entelechy.

The difference between Aristotle's and Driesch's conceptions of entelechy lies firstly in the manner in which the two men arrived at the idea. Aristotle, starting from Platonic metaphysics, sought for a road to objective reality. Driesch, starting from biological reality, sought to give it a strictly logical expression. For this reason Aristotle's conception of entelechy was a very much wider one than that of Driesch. It included the creations of the artist, and even the facts of inanimate nature, while Driesch merely applied the idea to biological processes. Secondly, Driesch's conception of nature was a quantitative one, while Aristotle was content with the qualitative view (for the Aristotelian entelechies were qualities). Driesch also leaves undecided the question whether entelechy, as the creative agent, is to be contrasted with dead and passive matter as something absolutely different from it (as Aristotle thought, when he separated matter and form).

Driesch used this idea of entelechy to build up his psychological theories. In these, too, his ideas were very closely akin to those of Aristotle. He does not believe in a psychology of consciousness, for he holds that we cannot affirm anything objective in regard to consciousness, since it is purely subjective. The only proper subject of psychological study is the organism in action. Similar features underlie the phenomena of behaviour (both of men and animals) and the phenomena of development. In both cases the actions are directed towards a certain end. In neither case can we think of them as purely mechanical, for they are directed by an idea. Let us take the case of

a dog who is making for home. All his movements are co-ordinated by and subordinated to his aim—to reach home. He avoids obstacles, finds the shortest path, and makes use of all his previous experience. The application which he makes of those earlier experiences is controlled by the special object which he wishes to attain. His progress is directed by something which is very analogous to the entelechy which controls and directs development. This something, which is very real, though intangible, and which is known only to the mind, was called 'psychoid' by Driesch. 'Psychoid' is already present in the newly born; it takes the form of an 'urge' towards action. This 'urge' is endowed with knowledge; this is clearly revealed in the first movements of the new-born animal. This innate urge and innate knowledge, which precedes all experience, were called by Driesch *primary purpose* and *primary knowledge*. Later on, when the organism has accumulated experiences, it regulates its activities according to these; such experiences constitute its 'secondary purpose' and 'secondary knowledge'.

§ 3. *Driesch's Logic.*

There have been many complaints of the obscure style of Driesch's writings. Why are they considered so difficult to read? Why have so few scientists attempted to discuss or to criticize the principles underlying his theories? The cause is not to be sought in Driesch's style, but in his peculiar mode of thought. It was said by Coleridge that every man is born either a Platonist or Aristotelian. Driesch is a Platonist, if he believes in intuition, if his objective thinking is by means of plastic pictures. He is an Aristotelian, if his convictions depend upon 'proof'. The difference can only be partially expressed by the deceptive words 'abstract' and 'concrete'. Platonic ideas are very 'abstract'; nevertheless they are, in general, much more comprehensible, and much nearer to reality than are the ideas of Aristotle—and this in spite of the fact

that Aristotle's ideas are much more concrete, dealing with such concrete themes as dynamics and 'energeia'.

Among modern writers Kant, Lotze, Darwin, Weismann, and Roux are to be numbered among the unimaginative 'proof-seekers', while Goethe and Schopenhauer may be cited as important disciples of the opposite school. The writings of the intuitive thinkers are very much easier to read. We do not have to search for each idea at the end of a troublesome proof; it is there, in every sentence, in every word. The only purpose of the detailed exposition is to give to this idea logical form, to define its shape and delimit its contour. In contrast with this, the scientist who deals in 'proofs' is not expounding an idea: he is seeking for 'truth', and is striving to distinguish truth from error. In this endeavour he employs nothing but logic, and for this purpose he strives to 'prove' that it must be so, and not otherwise. For this reason his thought seems to us to be very abstract. In his 'proof' there is nothing that can appeal to the imagination, while his appeals to the understanding, his constant demands upon it, make us feel unsafe. We involuntarily fear the false inference that may be lurking somewhere, hidden from us. Driesch is a 'proof-seeker' *par excellence*. His earliest theoretical work was very characteristic of his whole method. He began by inquiring in how far biology can be treated mathematically, that is, can adopt the methods of the most logical of the sciences, one closely akin to logic. In a second theoretical investigation, he asserted that no really fruitful natural science is possible without a definite theory of knowledge, and turned his whole attention to the relationship between causality and teleology—a subject which is pure logic.

He attacked the usual methods of biological classification, asserting that they 'lacked that character of inevitableness' which is possessed by a geometric class—by, for example, the geometric group of regular bodies. He tells us that he once believed in the mechanistic theory, but that he discovered his error when he attempted to follow

out this theory to its logical conclusion. In this way he had ultimately been led to declare himself a dynamic vitalist. When he has arrived at this position he begins to question himself anew—is he right in his conclusions? To this question he himself gives the answer:

'Such questionings are impossible—and they should never be formulated, either now or in the future. No new line of approach to these problems is possible. This is implied in our admission of the fact that the idea of "necessary connexion" is an *a priori* logical necessity' ('Kritisches und Polemisches,' *Biol. Zentralbl.* 1902).

He has become a vitalist; he does not claim to have presented this view in any new manner, but he believes he has demonstrated that it is the only theory which is intellectually possible.

This attempt to 'prove', to analyse logically; this constant striving for accuracy of inference; this 'intoxication of thought' for which Lotze was once reproached—all these render the works of Driesch almost unapproachable.

In his theoretical work Driesch was a follower of Roux and Weismann. They, too, believed that it is extremely important that every assertion should be logically 'proved'. But Weismann's logic consisted chiefly of ingenious deductions from hypotheses which have very little contact with reality, and are meant for the reader rather than for the author himself. Roux's work took the form of a dull and extremely specialized science, but Driesch broke away from this tradition. He endeavours to prove each of his statements to his own satisfaction, and is willing to take into consideration not only biological facts but also the opinions of philosophers.

Driesch left biology before the war, and became a philosopher. As such he is related to Kant. Like Kant, Driesch is endeavouring to formulate a pure and unassailable natural science—a science containing only propositions which are of universal application, and hence a science which will rise above every form of doubt. Driesch believes that he can attain to this by examining the most

fundamental logical principles. This was the aim of his book on *Ordnungslehre und Wirklichkeitslehre*. He was endeavouring to formulate axioms which would express the most general laws of natural science.

Driesch sought to go further than Kant, who had been accused of taking his categories (quantity, quality, relation, and modality) from earlier authors without first proving that they were logically necessary. Further, Kant's illogical attitude to subjective ideas had been severely criticized. Driesch attempted to correct these errors and make good these omissions. The categories are not merely to be thought of as indissolubly bound up with a subject, as necessarily part of an ego, of which they represent the qualities. They are more fundamental than this. The ego itself is the result of categorical thought, while the categories themselves are the result of experience—in its most generalized and extensive form. They are not inductions from experience, as so many English writers assert; but neither do they represent principles which precede all experience. They are first awakened by experience; it is then that we call them to mind, the experience providing, as it were, the opportunity. Hence Kant's discussion of the application of the categories to facts beyond experience and his formulation of a 'Thing in itself' are illusory.

Kant's treatment of categories formed the starting-point of the speculations of the Romantic philosophers. Fichte and Schelling, however, abandoned the formal, analytical methods of their master. Fichte asserted that logic is not a real science. It has for its subject-matter the processes of thought, and hence it merely subjects to analysis the real knowledge whose existence it must assume. Driesch, on the other hand, elaborated the formal and logical aspect of Kant's philosophy first of all.

Driesch paid special attention to the philosophies of Hegel, Schopenhauer, and E. von Hartmann, as well as to the views of Kant; to Hegel because he emphasized abstract logic; to Schopenhauer and Hartmann because they assumed that the will is the cause of all action. Fichte

and Schelling, on the other hand, have had no influence upon Driesch, for they did not adopt these analytical methods. Driesch did not follow the bad habits of most biologists, who look upon physics and chemistry as fixed and concrete sciences, whose conclusions they must simply accept. He examined the logical bases of these studies, criticized them, and compared their methods with the logical methods of the biological sciences. Thus he hoped to get a clearer picture of the whole problem.[1]

Others had assumed that the great difference between physics and biology was that the former science deals with general laws (the laws of refraction, Coulomb's law, Galileo's laws of falling bodies), while the biological sciences describe actual concrete objects, e.g. a horse or a rose. Driesch did not acknowledge this difference. Biologists in his view must also formulate reasoned conceptions which are of general application. Such conceptions as cells, chromosomes, vertebrates are not rational conceptions, but collective conceptions, analogous to the physical conceptions of heat and cold, and are arrived at by simple abstraction from separate facts. The rational and only really scientific conceptions, on the other hand, are intellectual ones, like those physical concepts of velocity, acceleration, and refractive indices, which the physicist has devised for the purpose of understanding events. In their methods, then, physics and biology are alike, but their objects are fundamentally different, for the latter is concerned with life, and life is governed by laws which are not the laws which govern the inanimate world.

§ 4. *Conclusion.*

Descriptive natural history gives us concrete events, as if these were the ultimate realities—it presents those events in the final form into which they have been moulded. Each fact, each event, is regarded as something

[1] Driesch discusses the relation between biology and other sciences most exhaustively in *Naturbegriffe und Natururteile*, 1904.

absolute; but the relation between the fact and the mind is quite a chance one. Driesch's views are opposed to this conception. He regards each event as predetermined, and logic is to him of paramount importance. Even descriptive science must use the methods of the logician, for our speech, the very words which compose it, our judgements and inferences are all manifestations of pure logic.

The student of natural history makes use of language, of judgements, and of inferences to describe his objects. But he believes that it is the description which is of primary importance, while Driesch holds that the only part of natural science which is of any real importance is its method. He endeavours to present as science only that which is logically obvious. Thus he very soon reaches *a priori* ideas—ideas which are obviously innate. This is not science—this abstract science which Driesch gives us, a science which is incapable of any further development, which has no joy in detail or in original discovery.

Is biology then only the application of theories of knowledge to the facts of existence? If so, what do our museums represent? What is the meaning of the joy experienced by the collector of plants and animals? What the meaning of the satisfaction aroused by the discovery of a new fact? What is the value of that innate curiosity which drives men on to new investigations?

In a somewhat different form Bütschli has advanced this same objection to Driesch's views:

'Apart from the fact that we do not study nature for the sole purpose of discovering her laws, but also because we desire to know something of the world in which we live, and of the universe around us, what, we may ask, is the reason of our interest in those laws—laws which can, as a rule, only be expressed as rather uninteresting mathematical equations?' (O. Bütschli, *Mechanismus und Vitalismus*, 1901).

There are, too, certain objections to the idea of entelechy; for example, that it gives us too atomistic a conception of the world. Driesch looks on such generalized

conceptions as 'vertebrate animal', 'form', 'thought', as properties of entelechy; he does not think that they, in themselves, have any real existence.

This leads him to a very peculiar conception of history. History, he says, is always the history of bodies. Histories of science and of art are histories of men, of pioneers, and of artists. Every history deals either with the development of a body; or with the history of some corporeal quality, occurring in a series of bodies which are produced in sequence, the one by the other; or finally (as in a history of Science), it is concerned with bodies which are only very indirectly related to each other, but of whom it is still true that each one has been produced by another of the series. History either gives us a picture of a development, as in the history of an individual, or it gives a culmination, linking up events with those that preceded them, as in a history of Science. Further, Driesch affirms that that history which is cumulative cannot be regarded as an exact science—a science with its own definite laws.

There have been endeavours, it is true, to create philosophical history—to present a history which describes the evolution of law, of culture, or of religion. But we have had to reject all such attempts, since they were all so inaccurate and inexact. Our study of history has not enabled us to formulate any general laws, and hence history cannot be regarded as an exact science.

What is it, then? How are we to classify the works of a Tacitus or a Taine? What is Driesch's own *History of Vitalistic Theories* ('Der Vitalismus als Geschichte und Lehre') if it is not a work of science? Driesch does not give us any answer to this question. Further, we cannot accept the view that Art and Science are nothing in themselves, and that the world consists merely of so many material bodies. All history shows us that this hypothesis is wrong. It shows us how, at this or that time, these or those ideas were predominant, and how some ideas, far mightier than any individual, subdued whole masses, whole nations, to their service. We can follow these ideas,

from their very inceptions, through their growth, to their time of triumph, and thence onward through all the processes of decay. To do this we do not need to know very much about the actual material 'bodies'. Christianity, Monasticism, the Reformation, the Revolution, the State, Science, Darwinism—all these denote something very real, something more fundamental than any mere aggregate of facts; there is a living idea behind each of them. A universal history (and Driesch was only considering universal history) is not necessarily written to present ideas —yet there were, and there still are, ideas behind any such history. The task of the historian is similar to the task of every other investigator; he must discover those ideas—for they alone represent what is constant in the never-ceasing flux of material phenomena—and he must describe their qualities. For the carrying out of this task the question 'Does an idea evolve?' is of minor importance. 'Did it exist?' and 'What was it?'—those are the questions of vital importance for the historian.

We see, from his view of history, from his manner of regarding it merely as the sum of the productive efforts of a member of separate individuals, that Driesch was still strongly under Darwinian influence, in spite of his attack upon the theories of Darwin. The older historians had believed that their task was to search history for ideas. This 'philosophical history' was first rejected by Buckle; he was the first to assert that the progress of civilization had been simply due to the accumulated efforts of individual men. Since his time this atomistic conception has been predominant. It has been specially prevalent in the writing of the history of Science; such history, it is thought, is nothing but the presentation of a series of new discoveries. This idea is also predominant in all Darwinian speculation. Darwin himself banished Nature, as a creative force, out of the realm of science; he it was who first declared that only separate individuals have any real existence. He attacked the ideas of species, of orders, of plans, and affirmed that such ideas do not correspond to

any existing reality. He forbade the search for ideas behind the history of organisms, and thought that the sole aim and end of science should be the explanation of facts.

Driesch agreed with Darwin on all these important matters. Driesch objects to mere descriptions, to all classifications arrived at by induction, since these only present us with facts, and not with facts which have been illuminated by the light of pure reason. He ridicules evolutionary trees as mere ancestral portrait galleries, in which we know nothing of the relationship of the various pictures. And yet—What was the true significance of Haeckel's stormy campaign? Was not he, too, claiming what Driesch claims, that we must abandon mere description, discard all those systems which we cannot explain, and work towards a higher science, by which we shall be able to 'understand' and to 'explain'? Did not Haeckel endeavour to explain the ancestral types which Cuvier had made known to us, not by entelechy, it is true, but by phylogeny? Driesch does not reject the ideas of phylogeny. On the contrary, he thinks it extremely probable that living forms are descended from one another in some such way as phylogenists suggest. But he wants to know exactly *how* the whole process happened.

There is another matter in which he shows himself to be your true evolutionary philosopher. He has proved, to his own satisfaction, that it is erroneous to speak of an Idea manifesting itself in the history of the world. Nevertheless he returns later to the subject and suggests that history does, after all, perhaps reveal some such Idea. True it is, as he assures us, that he cannot *prove* the existence of any such harmonious universal purpose; nevertheless he believes that there is one. From belief to acceptance as proved is but a short step. Driesch will not take that step, but there are many who do not hesitate to do so. Kant, too, had declared that the Absolute is never known and never can be known; yet his followers—the Romantic Philosophers—made this Absolute the basis of their philosophy, the only real thing left in the universe.

In reviewing the story of Driesch's work we see happening once more what may happen to any original thinker. He believes that he has discarded the Darwinian ideas, but in reality he has succumbed to them. This shows us that Darwinism is not so easy to refute, is not so easily uprooted, as it would at first sight appear. Who can say what depths of thought will be discovered in it by the generations yet to come—depths hidden from us, who stand too near to the whole story? We have only the first rude beginnings of all that discussion and criticism which will be necessary before mankind can form his final judgement.

Since the above chapter was written Driesch has developed his ideas still further. In his *Philosophy of the Organic World* he has left biology far behind; the work is pure philosophy: it deals with theories of knowledge and with metaphysics. Since 1905 Driesch's contemporaries have looked upon him as a philosopher rather than as a scientist.[1]

[1] Among the most important of Driesch's philosophical writings are: *Ordnungslehre*, 1912; *Die Logik als Aufgabe*, 1913; *Wirklichkeitslehre*, 1917; *Wissen und Denken*, 1919. O. Heinichen has given an account of Driesch's philosophy in his *Driesch's Philosophie, eine Einführung*, 1924.

XXXIII

DARWINISM IN DECLINE

§ 1. *Reaction against Darwinism.*

IN the 'seventies and 'eighties of last century Darwinian ideas dominated biological thought, and it was universally admitted that speculation in other fields of science was being strongly influenced by the same ideas. Investigations were pursued with one aim in view—inquiry into the causes of phenomena; the only questions discussed were those concerning the origin and ultimate fate of material things. Lichtenberg's nickname of *a cause-seeking animal* ('wahres Ursachentier') never fitted mankind better than during that epoch. The last anti-Darwinian works of any importance had appeared at the end of the 'seventies. The controversy still continued sporadically, the idealists still published an occasional protest (e.g. Michaelis); but no one paid any attention to them, though now and again there was an appeal for some form of compromise between the new teaching and the old belief in an Almighty God.

Delpino, a professor of botany at Genoa, accepted the Darwinian principle of Natural Selection (1880); nevertheless he pointed out that there is an enormous gap, which cannot be bridged, between the living and the non-living. He affirmed that, in the existence of sensation, of the understanding, of the will—in the whole range of life, from the amoeba to Man—the domination of an All-powerful Deity is manifested. The Darwinists merely shrugged their shoulders over such objections to their purely scientific ideas.

Natural history was looked upon as the most firmly established and the most progressive of the sciences, since it had succeeded in proving what all were anxious to prove: that matter and force are all-important—that idealism was dead. Proudly she endured the *odium theologicum* of the Church—that Church looked on helplessly while

her strongholds were overthrown by the spread of the growing conviction that a man is only a superior monkey. It was generally held that Darwin had succeeded in doing what the great revolution had failed to accomplish. Mankind had at last thrown off all the chains binding him to his own ethical, religious, and scientific past. A new era had dawned, dominated by a scientific outlook on reality. Psychologists, lawyers, philologists, sociologists, philosophers all admitted modestly that there was no finality in *their* sciences, and they looked up to biologists as the only possessors of absolute knowledge. Darwin, Weismann, and Haeckel were authorities who could solve every problem and banish every doubt.

This complete domination of contemporary thought by the Darwinian point of view did not last long. After the 'eighties one realm after another was lost to it, until finally it reigned supreme only in the field of biology. Zola was at the height of his fame in the 'eighties; yet in 1889 Bourget, in his introduction to *Le disciple*, rejected the idea that man is merely a bundle of natural instincts; he criticized the exaggerated cult of natural science, and pointed out that even science is full of mystery. The work of Brunetière, another critic of Zola, was very well received, and his protest against the scientific ideals of Condorcet, Comte, Renan, and Berthelot caused much discussion. His phrase 'the bankruptcy of science' (1895) passed from mouth to mouth, and neither in France nor in any other country was there an opposition strong enough to weaken the effect of this criticism. The time when a du Prel could assert that poetry represents an 'antiquated point of view', and that it would be exterminated by the advance of science, had passed. Decadents and mystics—followers of Neitzsche and of Bergson—grew rank and luxurious amidst the ruins of the scientific edifice.

Scientific philosophy, too, which deduced unwarranted conclusions from scientific hypotheses, is also in decay. Spencer's name is referred to less and less in books on philosophy. Haeckel's monism, once regarded as a very

important philosophical system, became the view of a very minor group. Taine is attacked as insufficiently scientific. Kant, Hegel, Schopenhauer, the Romantics, and Naturalism—all these are coming once more into repute. Interest in religion revives. Scientific attacks on the literal accuracy of the Bible are out of date; history, archaeology, and philology once more play their part in Biblical criticism. What is of even greater importance, we speak again of 'the necessity for religion'. Not philosophers only, but scientists too (e.g. Reinke), introduced the idea of God into their discussions. The times were gone by when Comte could speak of theology as 'a childish study'. Protestants (Harnack, Sabatier, &c.) united with Catholics (Loisy, Schell, and others) in the study of their subject with renewed interest. The struggle of the modernists for 'progress within the Church' was a sign of the times. In the sphere of ethics, too, the times when this was very strongly influenced by Spencerian dogmatism are long past—those times when ethical laws were believed to be merely the products of utilitarianism, and morality merely the result of our social life. Nietzsche adopted a Spencerian attitude. Many of his ideas are derived from evolutionary theories. His 'blond beast', his 'superman', his glorification of physical strength, his belief in a better future, all show how much he owes to Darwinism. But gone is the respect for natural science, gone is the belief in a merely sociological morality. 'Thus spake Zarathustra: "Look, I am sated with learning, like the bee who has collected too much honey. I want the hands which can stretch themselves out".' Nietzsche's moral laws are based on a belief in the importance of the individual. Spencer, the practical engineer, the believer in science, the champion of the 'average' in morality, the believer in the progress of society, gave place to Nietzsche, the poet and classical philologist, who paid with his own sanity for his hatred of average morality.

There came a reaction, too, against the evolutionary view of history. Some workers still believe that science should

formulate the empirical laws that governed past events, in the manner of Darwin. But the attempts initiated by Buckle and Taine to write history round these laws has long been abandoned. There is, it is asserted, a fundamental difference between the methods of the natural sciences and of the cultural sciences. Dilthey says that the historian must describe, not explain. He should portray typical phenomena, each with its individual characteristics; he should describe the actual events, rather than attempt to deduce general laws, as is done in natural science. Similar ideas have been expressed by Windelband, the philosopher. He places the writing of history among the descriptive (idiographic), natural science among the law-determining (nomothetic), studies. Rickert asserts that history and science are divided *toto coelo*; the former aims at describing the particular, the latter at deducing the general. Historians with any leanings towards philosophy have already completely discarded the scientific method of interpreting history.

Among social democrats the materialistic philosophy, which they adopted from the scientists, had reached its culminating point before the war. They have emancipated themselves from those purely rationalist views, deduced from a study of natural science, upon which Marx and Engels based their systems. Nowhere to-day, outside Soviet Russia, is the materialistic philosophy of Marx accepted as the basis of modern socialism!

Philology has long since freed itself from the shackles of Darwinism. Schleicher's pamphlet, which introduced Darwinian ideas into linguistic studies, appeared in 1863. In 1871 Whitney, an American philologist, criticized these views adversely. He held that speech does not develop independently of man's will; it is a function of human life, an element of culture, and it may be altered at the dictate of the human will. This criticism did its work. In 1880, when Darwinism in its application to biology seemed still to be full of life, Delbrück declared that Schleicher's point of view had been superseded.

In chemistry, astronomy, and petrography the attempts made to introduce the Darwinian point of view were abortive from the beginning. In no department of science, other than biology, is the Darwinian conception the dominant one to-day. Public attention is focussed on modern physics, as interpreted by Einstein and Planck.

§ 2. *Science Loses its High Reputation.*

Modern biologists hardly noticed how rapidly public opinion was changing. They believed that the reins by which our intellectual life is guided were still in their hands. The general atmosphere around them gave colour to this view. Sceptics might protest that Darwinian ideas were not applicable to their particular subjects, but they made no direct attack upon natural science, upon biology itself; they only pointed out that the biologists were not agreed about their fundamental principles. At this time Weismann's name was often cited in proof of the fact that the views of Darwin and of Haeckel were no longer receiving unqualified acceptance from biologists.

From the 'nineties onwards the positivist belief in the facts of science has been gradually undermined while the prestige of philosophy has increased. This movement resembles in many ways the German romantic movement of the early nineteenth century. Bergson was its protagonist. Beginning from the positivist point of view he discarded the nineteenth-century belief that the intellect is all-important. He relegated science to a place in the second rank. Its use is merely practical, for it adds to the well-being of mankind; it has not been able to discover absolute truth. Only when man's subconscious mind is saturated with ideas relating to the meaning of phenomena will he be able to obtain some clue to final causes. It is, however, true that, in spite of this, Bergson, in his most important book, *Creative Evolution*, links up his work with that of Spencer and Darwin. He is examining the same problem —the problem of the history of the organic world; he

discusses the transmutation of species and the differentiation of specific qualities. He tries to obtain some explanation of the upward tendency exhibited by organic life, and searches, as did Darwin, for the driving force which lies behind organic evolution.

Using very original arguments Bergson proves, however, that Darwinian theories do not really represent an effort to discover the history of events, to describe what actually happened. They merely display to us, in the manner of a cinematograph film, a series of forms which follow one another in time; it is possible to picture these as all having existed simultaneously. Evolution was not thus; it was a process of change, a continual process, an impetus. This, according to Bergson, has existed since life began as an *élan vital.* Bergson's theory did not directly influence evolutionary theories. But indirectly it was of considerable importance, for it added to the growing scepticism with which the Darwinian ideas were viewed.

§ 3. *Modern Physiology.*

The increasing importance attached to the experimental method is intimately connected with the rise of modern physiology. When the Darwinian influence was greatest Müller's physiology was looked upon as ideal. It was a very theoretical physiology, which regarded form as the most important quality of the organism, and endowed all forms with functions. Those who came after Müller restricted this aspect of their work to an examination of the sense-organs, regarding them simply as physical mechanisms (e.g. von Helmholtz Wundt); this work culminated finally in investigations which belong to the realm of pure physics and psychology (e.g. Mach.).

This physiology of the sense-organs, marked by a strong philosophical bias, attracted general interest. Pure physiology, however, was felt to be of minor significance, and was chiefly studied by the medical faculty because of its practical importance. The more Darwinism flourished

the more physiology declined. The physiologists seemed to be only interested in the nature of Man; they used animals (frogs, dogs, pigeons, rabbits, &c.) only for those experiments which could not be performed on human beings. The Darwinist could boast that *his* attitude was more philosophical and aimed at obtaining a more general knowledge of Nature. He only regarded Man as one organism, neither more nor less important than any other living form. Nevertheless, the evolutionary view was intimately connected with the physiological ideas prevailing at that time.

French physiologists were also influenced by current ideas, but nevertheless, led by Bernard, Bert, and Marey, they remained true to the experimental tradition characteristic of their country. Some of them (Bert and Marey) were to a certain extent believers in the evolutionary theory. The idea of 'general biology'—an idea which has played a somewhat important part in modern times—originated in France. The word 'biology' was introduced almost simultaneously (1802) by Lamarck and by Treviranus to indicate a science which dealt with the general problems common to all living organisms. Treviranus' work had no lasting effect. In 1838 Comte, however, adopted Lamarck's term to indicate a science, the subject-matter of which was the interaction between the organism and its *milieu*.

While Darwinism, based as it was on morphology and embryology, dominated the field of speculation, this word 'biology' could not take on any very definite meaning. It was often used indiscriminately; at one time to denote ethnology, at another oecology—the study of the habits of animals and plants—at another to denote biology in the Comtian sense. In modern times biology has come to the front as a subject of great importance; yet even to-day it is not quite clear what is to be understood by the term. It denotes at one time a series of general speculation concerning life, at another it is synonymous with general physiology, at another it means merely the study of the

cell. Nevertheless, since 1880, the term has gradually come to have a more physiological bias. There has been an attempt to connect modern general biology with the work of Comte.[1]

General biological studies represent attempts to widen the horizons of zoology and of anatomy by linking these subjects up with physiology. Physiology itself has also been revived from the decay into which it had fallen. Max Verworn's *General Physiology* (1894) aroused the interest of all biologists. The book is interesting for many reasons, and not least because it is the first, and perhaps also the last, Darwinian physiology.

We are all familiar with the physiological institutes of the great medical schools: masses of electric wires, rheostats, multiplicators, amplifiers, kymographs, respirometers, musical instruments, finely ground lenses, resonators—this physiology is certainly one of the most costly sciences to prosecute. On the theoretical side, too, it is difficult of approach. So much mathematics, physics, and chemistry are demanded as a preliminary. Verworn broke through the spell of this old tradition; while it lasted what had been done was perfected, but no new ground was broken. Verworn directed the attention of physiologists to the unicellular organisms; complicated apparatus and methods are useless here. All that is needed is a good microscope and a few simple instruments.

There were, however, many faults in Verworn's work. The greatest was that the author showed himself to be in favour of an ultra-conservative answer to every concrete question. His book soon lost its original reputation; it exerted very little influence on the later developments of modern physiology.

Loeb was the real founder of the modern school. He was a pupil of Goltz, a Strassburg physiologist who became famous for his experiments on the functions of the various parts of the central nervous system. In this work Goltz

[1] M. E. Gley, 'Les Sciences biologiques et la biologie générale', *Revue Scientif.*, 1909.

consciously allied himself with the French experimental school (with Flourens), and was opposed to the German anatomical work, such as was being done by Munk, Exner, &c.

Goltz showed that the structure usually found in each part of the brain is not absolutely essential for the carrying out of the normal function of that region; these functions may be performed by a brain that is damaged and imperfect. Function is higher than structure. Loeb applied Goltz's experimental methods to the lower animals—the insects, worms, and echinoderms; he was much influenced, too, by Sachs' work on the problems of plant physiology. In his early experiments he treated the animals purely as chemical aggregates, neglecting all the facts relating to structural differentiation or to systematic position. There could be no greater contrast than between this method and the Darwinian, and it led Loeb to some very far-fetched conclusions. The older view was that we must endeavour to explain animal vision by making a detailed examination of the structure of the eye; Loeb, however, considered that the structure of the eye is a *quantité négligeable*. All that matters, according to him, is light and the presence of certain chemical substances within the body.

Loeb afterwards settled in America, and the result of his marvellous industry was the new science of Comparative Physiology. In its broad outlines this new subject followed his teaching. No attention was paid to the facts of anatomy, but the organism was treated as 'a chemical machine consisting essentially of colloidal substances', a definition which mocks at belief in any deeper significance attaching to the facts of structure. Some of Loeb's theories are so far removed from any more profound view of life that we are almost tempted not to take them seriously. He asserts of memory, for example, that 'it depends in part on the nature of the fatty substances in the nervous system'. He thinks it possible 'that further investigations in this direction (on artificial fertilization)

will prove quite definitely whether and in how far the death of the adult animal is determined by the nature of life itself (i.e. whether death is a chance catastrophe which may be overcome)' (J. Loeb, *Vorlesungen über die Dynamik der Lebenserscheinungen*).

Loeb was, however, an original and versatile experimenter. It will be the task of the generation which is following him to revise his methods, and to take into account the fact that organic structure cannot be neglected.

In America Comparative Physiology is, with Evolutionary Mechanics and Comparative Paychology, the most popular branch of biology. Morgan, Wilson, Jennings, Yerkes and others are among the best-known workers in these fields. Such work is only very distantly related to Darwinism, and most of these workers pay little attention to the earlier views. In modern times very great interest is being evinced in the problems of heredity and of variability. These are being attacked with great enthusiasm, with the aid of modern experimental methods. They are looked upon as physiological, rather than as evolutionary problems.

§ 4. *The Doctrine of Expediency.*

When the enthusiasm for the idea of Natural Selection began to diminish it was pointed out again and again that organic adaptations cannot be completely explained by any merely mechanical principles. This argument was used to attack the whole evolutionary position; it is, however, only valid as a criticism of Darwin's *explanation* of expediency. It does not explain away the actual facts to which Darwin attached so much importance. There is, in organic nature, much that is expedient, and Darwin, in pointing this out, had sounded the death-knell of the older morphology. The facts connected with organic form were removed from the realm of metaphysics. Organisms were no longer looked upon as structures which were absolutely rigid and unalterable. They had, in the past, formed part of a science of philosophical morphology

which had much in common with Plato's philosophy. Darwin dragged them down from these metaphysical regions into daily life, and examined their immediate purpose in relation to the whole environment of the living organism.

He was, however, to a certain degree, still under the influence of the older point of view, for it was the static relation of the parts of the body to the environment that he dealt with. He regarded all plasticity, all power of change as something foreign to the organism, as something impressed on it by the action of forces outside itself.

More profound and, ta the same time, more concrete ideas were arrived at when workers focused their attention on this idea of purpose. All life was then regarded as imbued with purpose, and definite and purposeful reactions to definite stimuli were now examined, instead of the merely mechanical adaptations to such stimuli. For this reason physiology became the leading teleological science in the post-Darwinian period.

This change of ideas came about gradually. Pflüger was perhaps the first physiologist to examine the organ in relation to its purpose, from the physiological point of view. He formulated a 'law of teleological causality', according to which 'That which causes the desire in a living organism is at the same time that which leads to the satisfaction of the desire'. Food is the cause of desire in an animal; it at the same time satisfies that desire. In general, the law asserts that the organism reacts in a purposeful manner to the stimuli received from its environment. Giddiness is a purposeful reaction which warns us not to approach too close to a precipice. The repulsion we experience when in the neighbourhood of a corpse saves us from infection, and so on. Pflüger ascribes such reactions to the instinctive working of mechanisms which lie buried somewhere in the dim recesses of the unconscious mind.

Hartmann's *Physiology of the Unconscious* (1st edition 1869) represents an attempt at a compromise between the

mechanistic and the physiological-teleological points of view. He examines the regulatory mechanisms—both physiological and pathological—which are exhibited by the animal body, and describes its instinctive actions. He points out that these lead us to a conception of the animal, which contrasts in many respects with the views based on the facts of anatomy, and he pleads that the principle of teleology is at least as important as the principle of causality.

Pflüger and Hartmann did not exert any influence upon evolutionary thought.

After 1880 the idea was more and more often put forward that the purposefulness of life is a phenomenon *sui generis*, and that it cannot be explained as the result of a summation of chance effects. This was the view expressed in 1881 by Montgomery, an American physician who began to publish works dealing with the philosophical aspects of biology. The idea he developed was that the organism is quite different in kind from any inorganic substance; it does not represent an aggregate—not even a cell, tissue, or organ aggregate—but it is a unit which exerts definite control over the actions and reactions between itself and its environment.

According to Montgomery, it consists of a chemical substance which is destroyed by the action of the external world, which is renewed by its own activity, and which, by a process of development, forms organs for itself, in order to make its functional relationship with its environment a many-sided one.

Virchow's pupil Rindfleisch, who succeeded him as professor at Würzburg, advised 'due reticence in regard to the undiscoverable'; he laid great stress upon the specificity of living substance, and opposed Haeckel's views. The term Neovitalism is found for the first time in Rindfleisch's work (G. E. Rindfleisch, *Ärtzliche Philosophie*, 1888).

In 1889 the physiologist Bunge declared that he could not accept the mechanistic view, and pointed out how

important is vital activity. Rindfleisch and Bunge succeeded in interesting the public in their ideas, which were found to be stimulating, if nothing more.

After 1890 the teleologists increased rapidly in number. In that year C. Wolff published his attack on the theory of Natural Selection. He affirmed that the fitness of an organism for the life it is destined to lead cannot be explained; this must be accepted as a fact, an axiom. In 1891 Kerner von Marilaun, in his beautifully arranged book *Plant Life*, declared himself a vitalist. In 1899 Cossmann published a study in scientific methodology, in which he examines the relationship between causality and teleology; he declares the latter to be 'an unavoidable maxim for the critical judgement of biological phenomena'.[1] Since 1899 Reinke the botanist has come into the field in defence of teleological ideas, and has succeeded in awakening considerable interest in his views.[2] He declares that Darwin's idea, that the fitness of organism to-day is to be traced back to a lesser fitness in the past, is exploded. He regards the ultimate relationship of the organism to its environment as a fact which must be accepted—not explained. In order to make the difference between the teleological idea and the conception of a 'blind chance causation' comprehensible he postulates that there are two categories of forces at work within the organism; the 'energies'—identical with those forces known from chemistry and physics, and the 'non-energies', which he says may be 'systematic', 'dominating', or 'psychic'.

The systematic forces depend upon the structure of the organism. The way in which a watch goes depends upon the structure of its works; in the same manner thought depends upon the specific structure of the brain. Under 'dominant' forces Reinke includes all the 'self-formative'

[1] P. N. Cossmann, *Elemente der empirischen Teleologie*, Stuttgart, 1899. Bütschli, in the book to which we have already referred, mentions other vitalists, and further details are to be found in Driesch's *Der Vitalismus als Geschichte und als Lehre*, Leipzig, 1905. See also K. Braeunig, *Mechanismus und Vitalismus in der Biologie des 19ten Jahrhunderts*, Leipzig, 1907.

[2] Joh. Reinke, *Die Welt als Tat*, Berlin, 1899.

forces of the organism—those which have produced the organism from the egg. Such forces only exist in the organic world. They represent all that is really harmonious in that world; they control the development of specific structures, such as the eye, the ear, the brain, out of the plastic material of the embryo; they harmonize the various types of physical and chemical energy within the body, and produce a dominating control. Thus the way is prepared for those highest forces—the psychical, which are only possessed by man and the highest animals.

In a very able treatise Lawrence Henderson goes back definitely to the pre-Darwinian conception of the purposeful in the universe. He assumes that the present environment represents that best fitted to the life of the organism, because it is subject to laws which are advantageous to that life. The heaviest elements, for example, which are the least important for living organisms, are concentrated in the interior of the earth, while the lighter ones, out of which the living body is formed, are found at or near the earth's surface. The properties of water—so distinctive among liquids—fit it in a quite peculiar way for the part it plays in the living body. The properties of carbon dioxide are also adapted in a remarkable manner to the needs of living organisms. The properties of the elements are no chance properties. Carbon, hydrogen, and oxygen are all endowed with special characteristics which make them particularly suitable to form the basis of organic compounds. Henderson reminds his readers that his point of view is akin to that of the *Naturphilosophen* of the Deistic epoch.

§ 5. *The Crisis.*

Ideas are like men. They come into the world, but no one knows whence they came; they grow and flourish, and for a time cherish the illusion of eternal life, and then they depart into that land 'from whose bourne no traveller returns'. This was the fate of Aristotelian science, of the ambitious science of the eighteenth century, of Cuvier's

ideas, of naturalism; this fate is now rapidly overtaking Darwinism. Many still hold that Darwin was right, and proudly point out that no one has yet given any better explanation of the facts of animal history. This is true. But Darwinism is not being replaced by a better view; it is simply being abandoned. Not one of those who had become convinced Darwinists afterwards recanted—neither Darwin nor Huxley nor Spencer. But they grew old, they vanished from the world, and were replaced by new investigators, who had not experienced the vital glow aroused by the original Darwinism. They no longer understood its essential spirit; they have other tastes, other sympathies and antipathies, other experiences. In all this they differ from the originators of the theory. They no longer live in the theory, it is no part of them—they regard it as something extraneous.

Science lives in a new setting. There are no longer any great rhetorical upholders of naturalism. There is no need any longer to emphasize the accuracy of natural science. We no longer live in revolutionary times; the words, 'liberty, equality, fraternity', have lost their pristine attraction.

Famous names disappear from the field of action. Darwin is dead; and in that peaceful home to which philosophers from the whole world came as pilgrims a girls' boarding school was established. Huxley followed his friend, and his witty and sparkling essays are read less and less. Spencer is dead, and his philosophy is drowned in a flood of new systems. New names come into prominence, and a revision of values is in progress. To-day no one would speak as scornfully of Goethe as did du Bois-Reymond, that triumphant exemplar of the exact scientist. On the contrary, the reputation of Goethe, both as a biologist and a physicist, grows while that of du Bois-Reymond is constantly waning. Robert Mayer wins ever greater renown, while von Helmholtz, that pattern scientist, is quietly ignored. Naturalism is no longer banned; it is even threatening Darwinism. The biologists have changed

their methods. The prominent biologists of to-day do not produce works on comparative anatomy, on descriptive embryology, or on geographical distribution, subjects which were all of such pre-eminent importance in the period of classical Darwinism. Youthful scientists no longer grow intoxicated with the direct enjoyment of Darwin's monumental works. They only know a scholastic Darwinism which has been robbed of all its freshness and vitality; they no longer look at Darwin and Spencer with their own eyes, but through the eyes of Driesch and Roux, of Weismann and Sachs, of Nägeli, Haeckel, or Huxley. Darwinism, that bugbear of the reactionary, no longer exists. *Fuit Ilium!*

The first modern criticism of Darwinism—a very radical one due to Wolff—appeared in 1890, and since that date the anti-Darwinian movement has grown continually. This was not realized at first—it was thought that only minor matters were at stake, and people were guilty of extraordinary inconsistencies. It was felt that here was a new philosophy, and men endeavoured to grasp it, but their minds were still too full of the older ways of thinking. Ernst Mach, a physicist, revived the pre-Darwinian conception of motive as the logical cause of action. This was opposed to the evolutionary theory, in which the search for motives had been abandoned and had been replaced by the search for causes. Mach was absolutely unconscious of this antagonism, however, and held himself to be a perfectly orthodox and enthusiastic evolutionist. Ostwald spoke against materialism; further, he was bold enough to plead for the revival of naturalism. But his naturalism was a tune played on one string only, 'energetik', and it enabled him to introduce Darwinian concepts even into chemistry.

Yves Delage began to feel that biological science was facing a time of crisis. He was sorry that France was watching this general spiritual ferment so unmoved, and endeavoured to arouse the interest of his compatriots. Believing that French scientists were not sufficiently interested in theoretical work he collected all the biological

hypotheses which had gained a hearing, and published them in a great tome. But he did not produce the desired effect, for he was still immersed in Darwinian speculation and had not perceived the true nature of the controversy.

Studies of systematic biology, of anatomy, of embryology, even of the cell theory, become old-fashioned; new subjects hold the field. Just now it is physiology, experimental morphology, and heredity; their problems, methods, and inferences attract our attention, and accustom us to a new series of facts and a new logic. There is in all this no direct attack on Darwinism, but young scientists have their interests directed into other channels, and look upon the earlier work as old-fashioned and inexact. Many think they see a new dawn on the horizon; they write popular articles, in which they uphold teleology and vitalism, and attack Natural Selection, materialism, Darwinism, Haeckel, and Weismann.

Darwinism is called 'mere descriptive science'; even those corner-stones of Darwinism—scientific zoology and botany—are held to be out of date to-day—sciences which, in the 'seventies, dominated the world. To-day we all study general biology. In fifty years' time what new solution of these problems will thrill mankind? And where shall we find a still more general name for the biological science of that era?

We can find traces of this decay of positivist science, as this was understood in the 'seventies, in biology itself. In every department of human activity a definite conviction is of the utmost value. It carries us unharmed through the chances of the day, for we are led on to certainty. Until recently there was such a conviction in biology. There were doubters, it is true; there was no unanimity of opinion about the value of the theory of Natural Selection; there was uncertainty about the value of certain facts and theories. But all these minor differences were as nothing before the strength of the conviction that the Darwinian theory, and all that modern science which is based on facts, were wonderful edifices built on sure and lasting

foundations. The methods of exact science led men on eagerly to pursue new facts; so arose the fashion of announcing 'sensational discoveries'—discoveries which fly for a day from lip to lip, as great and epoch-making achievements, to be completely forgotten to-morrow. We have experienced a whole series of these in modern times: pithecanthropus; the chemical theories of instinct and of artificial fertilization; the idea that ants are mere machines; the proof that human blood is chemically akin to the blood of the monkey; cell physiology; the neuron theory; mutations; chromosomes; centrosomes; the theory of immortality, and so on. The sensational way in which scientists acclaim these facts, hypotheses, and theories, only to abandon them again as quickly, must bring science into disrepute.

Finally, Darwinism was completely rejected. In 1893 Driesch ventured to write that 'to examine the pretensions of that discredited theory known as the Darwinian theory would be an insult to the reader'. At that time no one paid any attention to Driesch. But he continued to develop his theory until it could no longer be ignored.

We may therefore sum up the modern position in Driesch's words:

'For those with insight Darwinism has been dead for a long time. The last pronouncements in its favour were little more than funeral odes inspired by the text *De mortuis nihil nisi bene*; they contained a complete admission of the inadequacy of the defence' (H. Driesch, 'Kritisches und Polemisches', *Biol. Zentralbl.*, 1902, p. 182).

Darwinism as a tyrannic doctrine, which imperiously enchains the minds of men, is dead. But it will continue to live as a great intellectual system worked out by men with great minds and of high ideals. In the future it will be included among the greatest of the ideas which form the legacy of the past; on it investigators of the future will train their intellectual talents.

XXXIV

THE NATURE OF SCIENTIFIC HISTORY

SCIENTIFIC activity to-day is based on the assumption that, if we increase the sum of man's inherited knowledge and pass it on to posterity, we are working for the general good. We hope by our science to widen the historical horizon. In the popular view real history—history and historical writing being regarded as identical—is the history heard in lecture-rooms, published in monographs, and treasured in libraries and museums. According to this view, there is very little value in the study of the history of a scientific problem, for exact science assimilates the past, so that the present includes the past.

This depreciation of the history of science began when modern scientific philosophy captured the imagination of the world. In the middle of last century, when the positivist idea of the progress of mankind was beginning to creep into science, into philosophy, and into politics, the history of science was a very popular theme. In France histories of zoology were published by Cuvier (1830–2), by de Blainville (1845), and by Geoffroy St. Hilaire (1854); a history of botany by Adanson (1864), and a very comprehensive history of palaeontology by d'Archiac (1864). In Germany, as the result of his study of comparative anatomy, Schmidt published a history of science in 1855. Inspired by Schelling and Cuvier, Spix started a history of systematic zoology (1811), while Sprengel (1817–18), and Meyer (1854), produced histories of botany. Carus' history of zoology (1872) also belongs to this period.

Even non-biologists like Comte and Buckle turned their attention to the history of science. Whewell's well-known *History of the Inductive Sciences* was the most famous of all these works on the historical aspects of the biological

sciences. Though its contents leave much to be desired, although its survey of the various branches of biology is very unequal in value, yet it has this great merit—its philosophy is original.

It begins with the assumption that there is progress in human affairs, and sets out to prove that in the history of science we can descry a continual progress towards ever-higher aims. The proof of this—which he proceeds to set forth in great detail—is that one science, Botany, proceeds along a direct and undisturbed road to its appointed end, while other branches of biological knowledge also advance, but less directly, making many false steps and many mistakes.

Whewell's belief in the continual progress of science had a decisive influence on later historians. Very soon it was not thought necessary to demonstrate this progress by any process of critical analysis; it was treated as a self-evident fact. This was very disastrous for the writing of scientific history; for if science is continually advancing the whole of its past is included in its present. All that the historian can do is to discuss its former errors; and this purely negative task is of little interest.

Some historians gave other arguments in defence of their subject. Cuvier gives a very clear summary of these in the introduction to his history. The study of the history of science is indispensable, he says, because (1) scientific theories rest upon facts, and it is the task of the historian to collect those facts; (2) the writing of history makes a repetition of work that has already been done impossible; (3) it helps to suggest new ideas, and so increases knowledge and inculcates the true scientific spirit.

History has not, in fact, played the part in teaching which is here assigned to it. No historical work has exerted any considerable influence on the views most widely held by modern investigators. The theory that science is an objective study, and independent of the individual worker, led to the assumption that each investigator either adds to the structure or does it harm; and

it was the task of the historical writer to determine the part played by each scientist in the building of the whole fabric. Some have done more, others less; hence we talk of an investigator's 'services' to science. We may open any modern book we care to choose, in which the development of a scientific investigation is described, and we shall find that the sole object of such a work is to give an account of the services of individual workers. But who can truly estimate the services of another? At the most, only another discoverer who can judge his predecessor's work by his own. The historian who is simply recording discoveries has no right to evaluate services. Hence he is made to feel that his work lacks all originality, that it lacks the true scientific spirit. Specialists look upon his work as popular.

Even when exact science was at the zenith of its philosophical reputation historical works dealing with it were rare. Histories of biology are merely lists of Darwin's 'forerunners', or historical introductions to various monographs. This represents a curious type of historical writing —it is really only make-believe history. The investigator, pre-occupied with some idea, seeks to explain his views to investigators who disagree with him. After considering the ideas of the living he passes to those of the dead, sifting out those theories which were akin to his own, or those opposed to his; he points out where these were right or where they were wrong, and in this way clarifies his own ideas. He makes a chronological list of his predecessors, and so produces a history. Such works—of which Sachs' *History of Botany* and Driesch's *History and Theory of Vitalism* are good examples—provide good foundations for the true historical writer; for when any investigator has formed an independent judgement about a problem his criticisms of other solutions of the same problem are bound to be illuminating. These works cannot be called historical works, however. All that they attempt to do is to show whether certain ideas were right or wrong. The true historian is not concerned with the correctness of ideas; he must regard them as events, as plastic realities.

In recent years biologists have paid much more attention to historical research. Having reached the end of a great creative period, we are looking back and endeavouring to see the whole story in perspective, to form a picture of what we have really lived through. Up to the present, however, such histories have been too timid. There has been no attempt to depart from the old well-beaten track which has been followed so long in the writing of biological history. They teach us nothing that could not be learnt just as well from a study of the science itself. Burckhardt's essay, *Biology and Biological History* (1909), forms an honourable exception to this rule. This author shows very clearly that the ideas underlying biological history are quite different from the ideas underlying biology. He affirms that the former must develop methods of its own, and expresses a hope that in the future the history of biology will, from the philosophical point of view, be as important as any other branch of history.

In the preceding chapters we have attempted to treat the history of biology from a new point of view. This has often provided the opportunity for introducing broad general principles which may perhaps be important in all historical writings. We may now, having reached the end of our task, discuss, in relation to what we have discovered, the true aim of all historical writing.

We read everywhere that science consists in a search for truth. The historian who wrote in the philosophical manner about the evolution of science also began from this maxim. Following it, he tried to picture science as something continually advancing towards truth and continually overcoming error. Many, of course, are striving after some ideal of 'truth'—many more, perhaps, than we at first realize. But this word 'truth' has more than one meaning. It is often affirmed that natural science is seeking 'truth', as opposed to 'error'; yet it is not this very abstract and logical truth which is the real driving power behind scientific research. History teaches us that the truth, which is the mere negation of error, exerts no very

strong influence over the minds of men. Directly Darwin published his ideas every possible argument was brought against them. Haeckel had to meet very severe criticism on the very threshold of his literary and scientific career, but all this criticism produced very little effect. The founders of Darwinism, however, were not posing as mere correctors of errors, as improvers of the old ideas; they were active protagonists of new ones. Kant and his philosophical work afford an excellent illustration of this truth. His work is really nothing but an essay in criticism, an essay in logic. This did not lead, however, to any still sharper criticism (i.e. differentiation of truth and error) from his followers. He became famous as the discoverer of the *a priori*.

The same is true of the efforts of individual investigators. In their introductions, of course, they affirm that they have undertaken the investigation in the interests of truth. They have set out 'thoroughly to examine the doctrine of the individuality of the chromosomes', 'to ascertain the meaning of the mesenchyme', or 'the function of the organ of hearing'. Usually, however, work dealing with such questions is actually begun because of a very successful preparation, or a chance observation made on material which happens to be available. The investigator is more often attracted by a *new* fact than by any abstract truth. This is true even when he formulates a new theory. His interest in it is first aroused because he seems to be discovering a *new* truth, and not because it affords a better explanation of facts already known. For even theories appear at first as fresh green boughs on the tree of knowledge; they become dry and brittle when they no longer represent new truths, but merely express logical ones.

The word 'truth' is very often used to denote some actual experience or fact, something of which we have direct knowledge, and which is not only true, but is concrete, having a definite form. The blue sky, Darwin's theory, the division of labour in the animal world—all represent such realities. The history of biology, like every other

intellectual pursuit, is the study of these realities. The task of the biological historian is not to discover logical truths, but those living ideas which shall guide investigators, which shall force research workers to attack definite problems, to review their facts from a certain fixed point of view, and to believe in definite theories. This may lead an investigator to a distorted conception of reality, but it is what we mean when we say of him 'he has an idea'. An idea is something original; it is not just learnt, nor is it arrived at by any conscious process whatsoever. An idea must underly every scientific activity; hence ideas are the more fundamental, and so the greater, realities.

The theories of Darwin, of Wallace, and of Erasmus Darwin were ideas of this type. They were not hypotheses which were acquired or suddenly made accessible; nor were they 'points of view'; but were direct convictions which gradually arose in the minds of their discoverers. If a student discusses Darwin's fundamental ideas, or a writer says that he believes in Darwin, these people are not really expressing 'ideas' of this type. To some readers it will seem strange that we accentuate so strongly the fact that science is dominated by ideas which are original products of the human spirit. Modern theories about scientific activity do not, however, recognize the existence of any such inspirational ideas. When the evolution of a theory is discussed we speak of 'ideas thrown out', of hypotheses, of proved facts. But in all this we are only describing the method; we learn a great deal about the care and industry with which the scientist has investigated his problem. But we completely ignore the *punctum saliens*; to 'throw out' a suggestion, we must first of all formulate that suggestion.

We often read, it is true, that the suggestion was made by some previous worker, but the proof added later by a subsequent investigator; it is to the latter that the credit of making a new discovery then belongs. Experience shows us that truths which are eventually confirmed are not stumbled upon in this haphazard manner. Should such

a thing happen, the discoverer would simply not believe in his discovery. It would seem to him as valueless as is a Latin word to a man who knows no Latin. If he does believe in its truth, it represents an idea, and it is the task of the historian to show how he conceived that idea.

Science and the Presentation of its History.

The difference between science and the presentation of scientific history is like the difference between nature and natural science. The first is fundamental; the second represents our views of the nature of that which is fundamental.

Modern science is not alive to this difference. Materialists and idealists alike seem to consider that Nature is identical with our picture of Nature; the former declare that it is Nature which is real, the latter that it is our picture which is real. We will not go any further into the philosophical aspects of this problem; there is, however, in practice, a difference between the object and the knowing of that object. Suppose we declare that animals, plants, and cells are merely ideas. We are all aware that these ideas relate to something which is more material than are our opinions, hypotheses, and assertions. Suppose we assert that a plant is a structure composed of cells. There is underlying this assertion some reality, the nature of which is not exhausted by the assertion that 'the plant is composed of cells'. The artist will give another definition, and the chemist still another, of the same plant. Even science defines the same plant differently at different periods. Our conceptions, then, are mere shadows, mere reflections of reality. Even when they are true, they only penetrate, to a greater or lesser extent, into the actual nature of the reality. Although it is not admitted, this is also true of history and of historical writing. Historians assume that all that survives from the work of each scientist is the work incorporated in and accepted by the science of their time. It is this, for example, which leads to the endeavour to prove that Darwinism is still believed

in; it is for this reason that the 'decline' of Darwinism sounds so ominous in our ears. This is why we are only interested in earlier investigators if we consider that they discovered new 'truths'.

There is a certain greatness about this conception to which Nietzsche has given expression:

'Every great man has a retrospective influence. Our reading of the whole of history is revised for his sake, and hundreds of the secrets of the past crawl out from their hiding-places—out into the sun.

'We cannot possibly foretell what minor incident will form a part of history in the time to come. The past is still largely undiscovered. It requires so many of these retrospective influences.'[1]

If this is true, then the past does not coincide with our picture of it, nor with the picture of it which will be painted by our descendants; it does not coincide with the picture of it formed by any man or at any epoch—it is quite independent of all this.

What we learn to-day about Darwin or Cuvier or Newton does not make those investigators live beyond the grave. All that lives is our conceptions of them; these we build up from the documents which those investigators left behind them.

Suppose there had been no such documents. Their immortality would not have been diminished in any way, but our conception of it would have suffered.

Or is it perhaps true that our knowledge of an object does influence that object in some way quite unknown to us?

The Recognition of Ideas.

We all agree that to proclaim a truth is one thing, but to help it to gain general acceptance is quite a different task. We realize that science recognizes many theories which are not 'truths'; that, on the other hand, there are many truths which mankind, including the scientist, refuses to accept. This is true, even of historians—they, too, only

[1] F. Neitzsche, *Die fröbliche Wissenschaft*, 1906.

accept those truths which have won general recognition. They do not trouble very much about the pioneers who failed to obtain recognition, and who suffered in their conflict with society, though they often ask how we may avoid similar occurrences in the future. They feel themselves competent to criticize general conditions, or to discuss definite persons. But there is one thing they never do: they never show that unrecognized truths are always in existence, side by side with those which have won acknowledgement; nor do they realize that the historian must take cognizance of both groups. Probably one of the most fundamental characteristics of an original idea is that it 'will out', that it strives for recognition; its bearer is driven to declare it, to fight for it—yea, only too often, to suffer for it.

> Whence comes our Time's dull discontent,
> Its rancour, haste and weariness?
> We're doomed to die at life's grey dawn,
> And hence the joyless dreariness.
> We long desired the Light we shall not know:
> In the chill dawnlight to the grave we go.

In these moving words Lenau has given voice to the passionate desire of his generation for truth. Can we doubt that the spirits of our pioneers are still troubled with this same haste, this restlessness, this weariness?

Thousands of ideas present themselves and fight for recognition. Most of them are buried in the distracted souls of a listening world.

The historian must not shut his eyes to these facts. He must search for truth everywhere, not only there, where it has received public recognition, but wherever mankind is thinking. He must not forget that even to-day, and even in the world of science, those glorious words which were spoken two thousand years ago are still applicable: 'A kingdom not of this world.' By the play of circumstances an idea is sometimes promoted, sometimes suppressed. An historian must not allow this to influence him; his task is to recognize ideas, not to paint the successes

of this world. He must recognize every new thought, even if, in the clash of ideas, it vanishes and leaves no apparent trace. It is still a fact for the writer of history, for it is a truth, and belongs therefore to that world of truths in which the historian lives, moves, and has his being. He must recognize the truth himself; he must not wait until it is forced upon him from outside by the pressure of public opinion.

Only too often he has cause to call to mind the words of Feuchtersleben:

> Nothing, cry they, all unknowing,
> Comes of labour, naught to see!
> All this time is Greatness growing
> Silently.
> Manifest, yet still un-noted
> 'Mid the world's confusing cry,
> She, to lowliness devoted,
> Passes by.

The more earnestly the historian strives to pick out this 'humble greatness' as it passes, to recognize it amidst the whirl of conflicting opinions, the more nearly does he deserve the title of Discoverer, Philosopher, Great Man.

N.B. The translator is indebted to her colleague, Miss F. Gibbons, for her kind help with the translation of the foregoing two lyrics.

INDEX